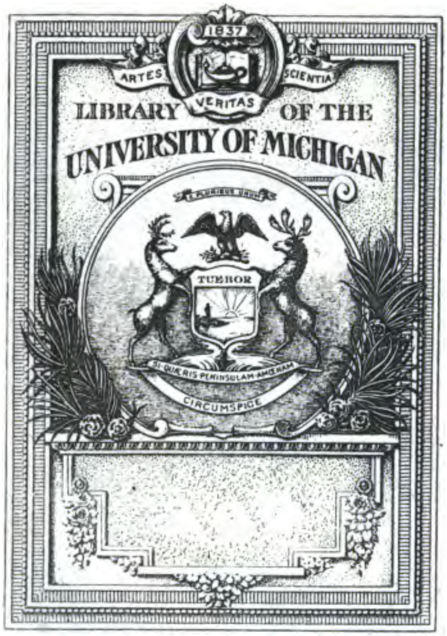
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LIFE IN PONDS AND STREAMS

PLATE I.

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LIFE

IN

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BY

..URNEAUX, F.R.G.S.

AUTHOR OF

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WITH EIGHT COLOURED PLATES

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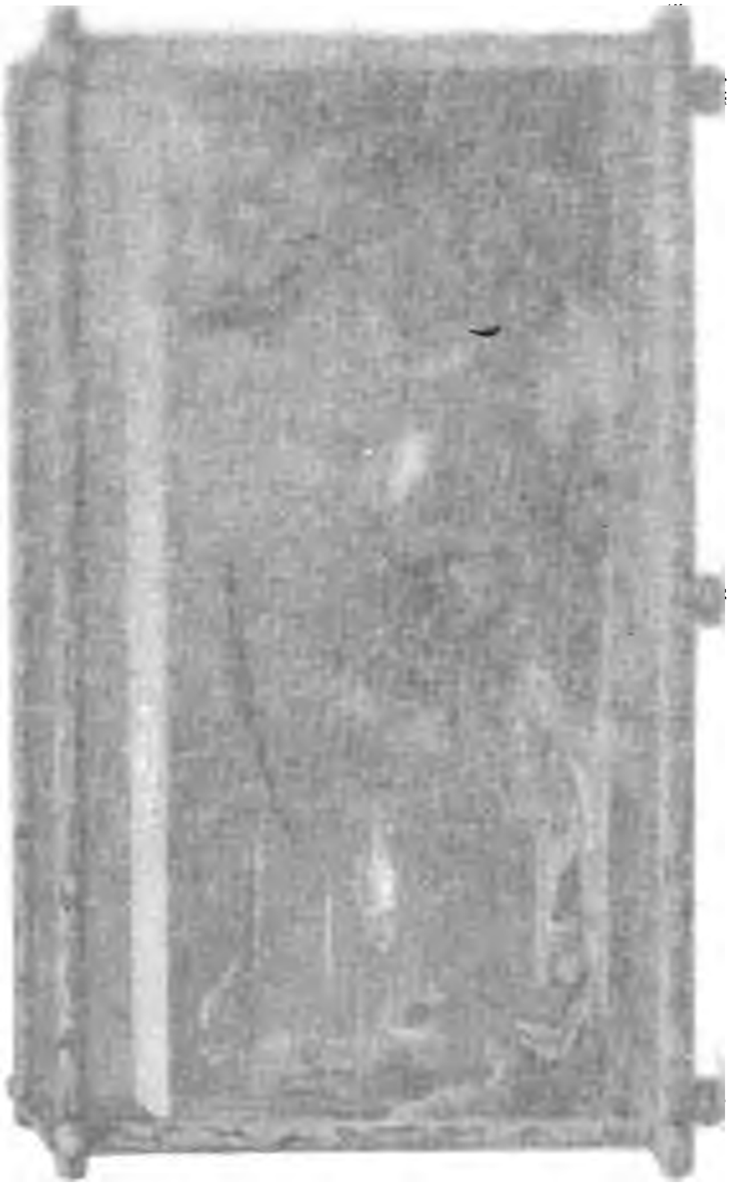

LIFE

IN

PONDS AND STREAMS

BY

W. FURNEAUX, F.R.G.S.

AUTHOR OF

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PREFACE

To a lover of Nature, all forms of life are interesting. But so numerous and varied are those forms that few students are able to give much time to the pursuit of more than one or two branches of Natural History. It is not to be wondered at, therefore, that most young naturalists devote their energies to the study of the more conspicuous and attractive creatures of Earth. Thus it comes to pass that a certain few of the orders of Insects have quite an army of enthusiastic students, that the beautifully marked and exquisitely formed shells of our marine Molluscs are eagerly sought after, and that our feathered friends and their eggs are well known and prized by many lovers of wild country life; while the study of the varied living forms inhabiting ponds and streams, most of which are not to be obtained without more or less careful searching for them in their haunts, has but comparatively few devotees.

But there is no reason whatever why the study of fresh-water life should not be quite as fascinating and instructive to even the youngest naturalist as that of the more popular branches we have specified above, and the chief reason why the weedy pond and the winding stream are so generally neglected is probably that our young naturalists have not had their attention sufficiently directed to the world of interest that awaits them if they will pursue their investigations of aquatic life with the same ardour that the collecting of butterflies or birds' eggs generally excites.

Let my readers, net in hand, ramble to the neighbouring ponds and streams, following the simple instructions given in these pages, and they will find that everywhere the water teems with life, and yields such a charming variety of forms as can hardly be found elsewhere within such a small space.

It is with the object of directing young observers of nature to these productive fields of labour that so much space has been devoted to the practical side of the work; and if those who are led to take up this interesting branch of natural history will carefully follow the instructions given for work in the field, for the management and rearing of creatures in the aquarium at home, and for the preservation of interesting specimens to be examined at times when out-door study cannot be pursued, they will find themselves amply rewarded.

The abundance of illustrations will, it is believed, greatly assist the pleasant labours of the worker in this department of animal life; and, to add to the interest of the subject, much space has been devoted to an account of the habits and life-histories of the creatures described.

But simply to *read* about the denizens of the water is not to know them, and therefore the young student has been encouraged throughout to make his own independent observations.

It must be admitted that the study of pond life is very comprehensive, since nearly all the great divisions of the animal world have freshwater representatives, and the number of species is so great that it would be quite impossible to include more than a small proportion in a volume of the present dimensions; but a very careful selection of typical species has been made, and every member of certain small groups (*e.g.* the Amphibians) has been described as their importance or commonness seemed to justify such a course.

W. S. F.

CONTENTS

PART I

THE COLLECTOR'S WORK

PART II

LIFE IN PONDS AND STREAMS

LIST OF ILLUSTRATIONS

COLOURED PLATES

ILLUSTRATIONS IN TEXT

PART I

THE COLLECTOR'S WORK

CHAPTER I

INTRODUCTION

NOTHING need be said by way of encouragement to those who have already examined a few hauls from a standing weedy pool, or who have gathered the moving forms that inhabit the overgrown banks of ditches and streams. The variety of living beings that frequent these places is so great, and their remarkable antics are so pleasing, that each dip of the net supplies the stimulus for the next, and each outing spent in searching for aquatic life intensifies the love of the pursuit.

It may be thought that pond and stream lose their charm for the naturalist who, from long experience, has already become acquainted with what they are capable of yielding; but this is not so. Who can say that he has ever *seen* all the species that frequent a stagnant pool? Or who can aver that he is thoroughly instructed as to the life histories and habits of even the commonest forms that are taken at almost every dip of the net? In fact, it is just here where the attraction lies. Unknown beings are continually making their appearance, and the old and apparently well-known friends of the collector are ever and anon exhibiting some new phase, or displaying some peculiar habit hitherto unnoticed. And it is this remarkable variety of aquatic forms, the equally remarkable diversity of their movements, and the almost continual appearance of something new, that puts pond-hunting at least on a level with some of the most popular pursuits of the naturalist.

Let us briefly survey the whole animal kingdom, noticing the broad features of classification, and then see how far the various classes are represented by the inhabitants of our ponds and streams.

The animal kingdom is divided into several groups, often termed sub-kingdoms, each one of which includes a number of creatures that possess certain characteristics which are common to all, and by which they may be distinguished from the members of the other groups.

As may be expected, no two authorities entirely agree in the details of their arrangement of the multitudinous and varied forms of animal life; but we shall confine our attention to the broad principles of classification only, and consequently shall not tread far on debatable ground.

The groups above referred to are eight in number, seven of which include animals that possess no internal skeleton of bone, though they are frequently supported by deposits of limy, silicious, or horny matter, forming in some cases a well-developed external covering. These seven groups constitute a very extensive and varied division of the animal kingdom known as the *Invertebrata*, or animals without backbones; and the remaining group—the *Vertebrata*—include all creatures that have internal bony skeletons, the main portion of which is the backbone or *vertebral column.*

The following is a tabular arrangement of the eight groups, commencing with the simplest forms of life, and taking each of the others in the order of complexity of structure.

Animals without backbones:

1. *Protozoa*—Simplest forms.
2. *Porifera* or *Polystomata*—Sponges.
3. *Cœlenterata*—Jelly-fishes.
4. *Echinodermata*—Starfishes, &c.
5. *Vermes*—Worms.
6. *Mollusca*—Mussels, Snails, &c.
7. *Arthropoda*—Animals with segmented bodies.

Animals with backbones:

8. *Vertebrata*—Fishes, Reptiles, Batrachians, Birds, Mammals

The first of these groups—the *Protozoa*—contains the lowest forms of animal life, the bodies of which consist each of a minute speck of transparent substance that generally exhibits no differentiation of structure. There is no internal cavity to represent the body cavity of higher forms, and no nervous system, nor are there any special organs to perform the functions of digestion, circulation, or respiration.

These creatures, in fact, are mere specks of living jelly, often without any kind of hard support whatever, but sometimes protected by a perforated shell of calcareous matter, or a delicate network or basketwork of silica.

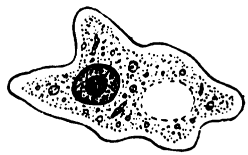


FIG. 1.—THE SIMPLEST OF THE PROTOZOA (*Amœba*), MAGNIFIED

Most of the *Protozoa* move about freely by means of temporary prolongations (*pseudopodia*) of their jelly-like substance. These 'false feet' are sometimes short and blunt, and sometimes are long and threadlike. Their mode of feeding is strange. Having come in contact with an approved morsel, the creature will surround it with two of its short temporary feet, or pull it towards its body by means of some of its long and slender 'arms.' The gelatinous substance of its soft body then extends itself round the desired particle, which is thus brought within the organism; and, there being no special digestive organ, any part of the body is capable of digesting the meal.

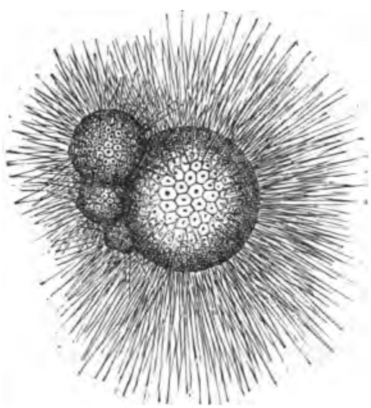


FIG. 2.—A PROTOZOON (*Globigerina bulloides*) WITH A PERFORATED CALCAREOUS SHELL, MAGNIFIED

Equally curious is the method by which these simple animals multiply. As a rule they increase by a division of their bodies—each one dividing into two, these two afterwards dividing again, and so on. But some develop buds, which break away and soon reach maturity.

The *Protozoa* include a number of the inhabitants of stagnant pools, some of which will be described in a future chapter. In addition to these, the group includes the *Rhizopods*—a class of marine animals, the bodies of which are protected by beautiful little shells; and the *Radiolaria*, also marine, the delicate netted silicious skeletons of which are commonly found among the dredgings of the ocean. There are also parasitic members of the *Protozoa* that live and feed within the bodies of insects, worms, and other creatures.

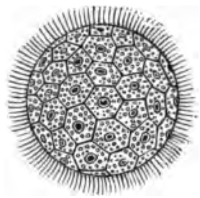


FIG. 3.—A COMPOUND PROTOZOON (*Magosphæra Planula*), MAGNIFIED

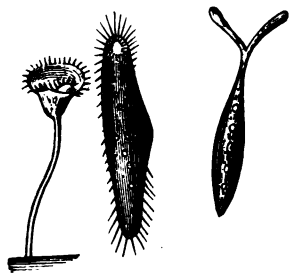


FIG. 4.—THREE CILIATED PROTOZOA (*Infusorians*), MAGNIFIED

The second group—*Poriferata* or *Polystomata*—includes the Sponges. These also are very simple animals, but differ from the *Protozoa* in that they have a body cavity, with large outlets and many smaller inlets, and are surrounded by a jelly-like wall that consists of two layers. The delicate structure of the body is supported by a skeleton which is sometimes horny and fibrous like that of the common toilet sponge, or is calcareous or silicious.

FIG. 5.—SILICIOUS SHELL OF A *Radiolarian*

These creatures multiply by division, and may even be increased artificially by cutting them into pieces, as each piece soon develops into a complete sponge.

Most of the species are marine, and in several cases their skeletons are familiar objects of beauty, notably those of Venus's flower-basket and Neptune's cup. Several of them are common objects on our own shores, and one or two species inhabit our ponds and canals.

The third group is the *Cœlenterata* It includes a great variety of animals which, together with those of the following division, form the 'chaotic group' that was once designated by the term *Radiata*, their bodies being all formed of a number of parts arranged symmetrically round a common centre.

The *Cœlenterata* have bodies of a gelatinous, gristly, or leathery nature, and the body cavity has only one opening—the mouth. This opening is surrounded by contractile arms or *tentacles*, by means of which the creatures seize their prey, and which are occasionally used for locomotion. The tentacles are also provided with stinging cells to paralyse their victims.

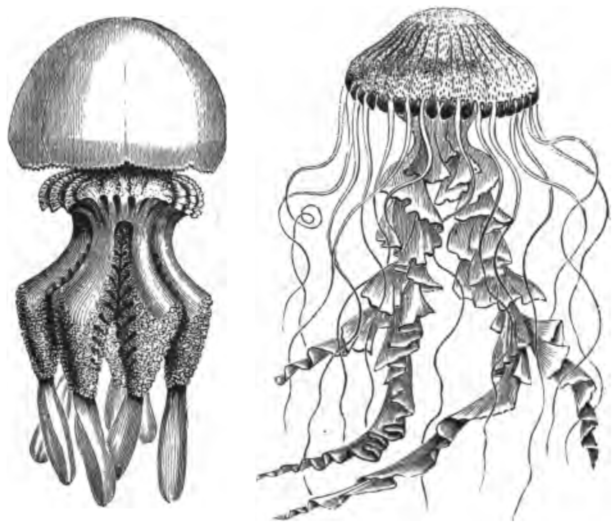


FIG. 6.—JELLY-FISHES—EXAMPLES OF *Cœlenterates*

In many instances a portion of the body cavity is partitioned off to serve as a stomach, but in some of the simpler forms the general cavity itself is the digestive organ.

The members of this group are mostly marine, and include the Sea Firs, which live in colonies, several individuals being attached to a common stalk; the 'Jelly-fishes' so commonly washed upon our shores; and Sea Anemones and Corals, some of which are solitary, while others live in colonies, some having stony skeletons and others being without any kind of hard support.

The *Cœlenterata* are very poorly represented in fresh water, but they include the interesting little *Hydra* of stagnant pools which will be described later on.

The *Echinodermata*, or spiny-skinned animals, will not claim any of our attention since they are entirely marine. The group includes Starfishes, Sea Urchins, and Sea Cucumbers, all of which have hard spines projecting from their bodies. Their bodies have also a radiating symmetry, and contain a system of water tubes which serve as a means of locomotion.

The fifth group is the *Vermes* or Worms, distinguished by their soft and elongated bodies, which are formed of a long chain of ring-like segments of similar structure.

The animals of this division have generally a distinct nervous

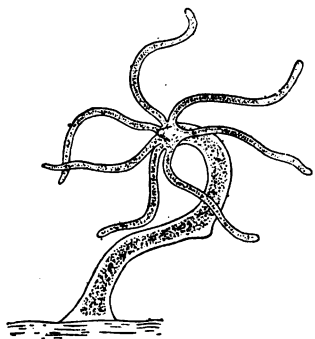


Fig. 7.—The Hydra, enlarged

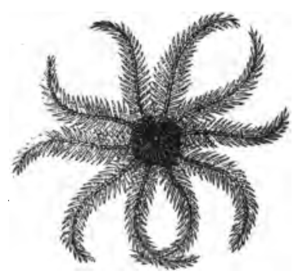


Fig. 8.—The Feather Star: an *Echinoderm*

system, consisting of a few little masses (*ganglia*) of nerve substance round the fore part of the digestive tube, and a nerve cord passing from these along the body beneath the same tube. They are also frequently provided with a system of blood-vessels, but, although the main vessel may be contractile, there is no true heart for the propulsion of the blood.

This group is fairly well represented in fresh water, but the most interesting as well as the most beautiful species are to be found among the marine members. It includes the somewhat slug-like *Turbellarians*, some of which inhabit stagnant freshwater pools; the parasitic Tapeworms, Flukes, Threadworms, &c., that commit their ravages within the bodies of man and beast; the remarkable little Wheel-animalcules (*Rotifers*) of stagnant water; marine Squirts; Leeches; the tube-building worms of the sea shore; the Sea Mouse; the Earthworm; and the gregarious Moss Polyps, a few of which live in fresh water.

It will thus be seen that the *Vermes* is a very extensive group, containing a great variety of animals, many of which are so characteristic that they have been placed by some eminent naturalists in separate divisions.

The sixth group—*Mollusca*—is one full of interest to the pond-hunter, as it includes a considerable number of creatures that are very ornamental and even almost necessary in the aquarium, and whose shells are in themselves worthy objects of study.

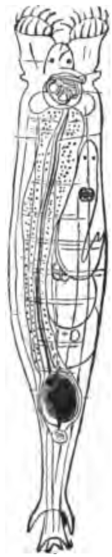


Fig. 9.—The Common Rotifer (*Rotifer vulgaris*), magnified

Fig. 10.—The Leech

Most of the Molluscs have not the slightest trace of an internal skeleton, but many of them are protected externally by a calcareous shell. Their bodies are soft, and generally covered with a soft but tough and thick tunic or mantle. They all have a digestive canal, and many of them are provided with a large number of small teeth which they use to rasp away the solid matter on which they feed.

The nervous system consists of a ring of nerve substance round the front portion of the digestive tube, and many members of the group have special sense organs. They have also a contractile heart with two or more cavities, but have no system of special vessels for the conveyance of blood, that fluid being forced into and through the spaces between the various organs.

There are three classes in this group. The first contains the two-shelled or *bivalve* molluscs, such as oysters and mussels.

These have no heads, and breathe by gills. Many of them are freshwater species. The second class contains the headed molluscs, such as limpets, snails, and slugs. Most of these are enclosed in a single shell, like the common garden snail; but some have none at all, and others only a rudimentary shell—a small calcareous plate, or, perhaps, only a few granules beneath the skin. The aquatic species, which include freshwater snails, breathe by gills; and those which live on land have a breathing chamber, corresponding with the lungs of higher animals, communicating direct with the air. The third class contains the more highly organised nautili, cuttlefishes, squids, and other marine species.

The next sub-kingdom—the *Arthropoda*—is the last and most highly developed of the Invertebrates. It is, moreover, a very

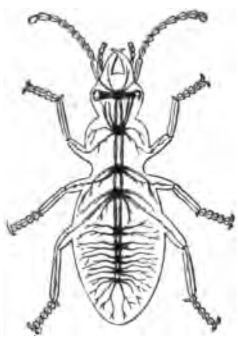


FIG. 11. — NERVOUS SYSTEM OF AN ARTHROPOD (BEETLE), SHOWING THE CHAIN OF GANGLIA, THE DOUBLE NERVE CORD, AND THE SMALLER NERVES

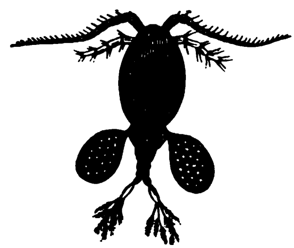


FIG. 12.—CYCLOPS, WITH ITS EGG SACS, MAGNIFIED

extensive group, and contains a variety of creatures of very great interest to the pond-hunter. Their bodies are covered with an exoskeleton of hardened skin, sometimes of a horny character, and sometimes calcified by deposits of carbonate of lime. In each case, too, the body consists of a number of segments, movable one on the other, and bearing each a pair of appendages, some of which may be described as limbs, while others serve the purpose of jaws or mandibles, or develop into long and slender antennæ, or constitute a stalk on which the eye is mounted. Most of the arthropoda have a heart and blood-vessels, the former being divided into chambers by means of valves; and also a distinct system of organs for respiration. The nervous system is generally of a complex character, consisting of a large ganglion, corresponding to the brain of vertebrates, which supplies nerves to the organs of the senses; and a chain of ganglia extending through the body.

This very extensive sub-kingdom contains four classes:

1. *Crustacea*—Crabs, Lobsters, &c.
2. *Arachnoidea*—Spiders and Mites.
3. *Myriapoda*—Centipedes and Millepedes.
4. *Insecta*—Insects.

The Crustaceans are nearly all aquatic, and breathe either by gills or by the absorption of air through the surface of the body; and they pass through a series of changes during their early stages, the young animal, known as the *larva*, being often very unlike the adult. The freshwater species include crayfishes, freshwater shrimps, water fleas, and cyclops, all of which will be hereafter described.

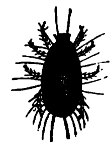


FIG. 13.—CHEESE MITE, MAGNIFIED

The *Arachnoidea* may be known by their four pairs of walking legs, and by the division of the body into two distinct parts, usually united by a narrow waist. The foremost of these divisions consists of the combined head and thorax, and the other of the limbless abdomen. The familiar garden and house spiders are typical examples; and the mites that feed on our cheese and sugar, the 'itch insect' and ticks, and the chelifers that find a home between the leaves of old books, are also members of the class; but the only species that directly concern us now are the aquatic spiders and mites.

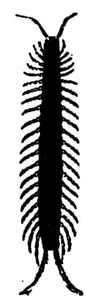


FIG. 14.—CENTIPEDE (*Lithobius*)

The next division of the Arthropods—*Myriapoda*—contains the few centipedes and millepedes that live in damp places, under stones, or in rotting wood. They have elongated bodies, composed of a large number of segments, each of which bears a pair of short jointed limbs. They obtain the air they require, direct from the atmosphere, through a system of air tubes (*tracheæ*) that open on the sides of the body.

We now reach the interesting class *Insecta*, which contains such a host of living creatures, with such great diversity of habits, that it is represented everywhere and at all seasons of the year. Some of its members are almost purely aquatic, spending only a few days or hours of their whole existence on land or in the air; some are purely terrestrial, living either under the surface of the ground, or in sheltered chinks and crannies above, and feeding on exposed animal or vegetable substances. A large number are provided with organs of flight for a longer or shorter period.

Insects may be known by the division of their bodies into three

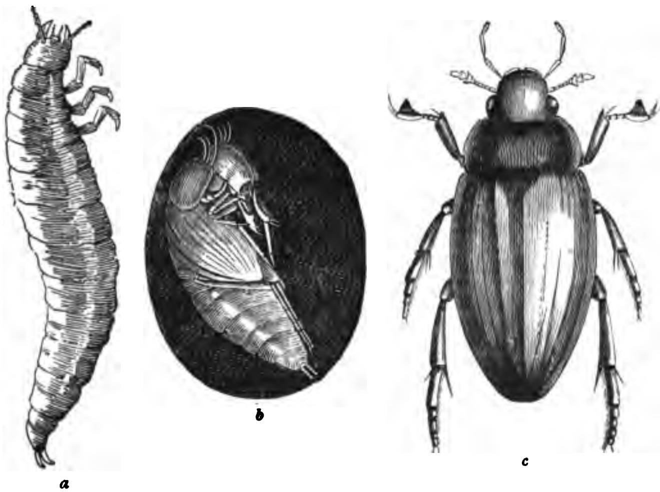


FIG. 15.—THE THREE STAGES OF AN INSECT (THE BLACK WATER BEETLE, *Hydrophilus piceus*)

a, larva; *b*, pupa; *c*, imago

more or less distinct parts—the head, the thorax, and the abdomen. They have also three pairs of walking limbs. The thorax is composed of three annular segments, each of which bears one pair of legs; and, in the case of the aërial species, the middle segment bears a pair of wings, while sometimes an additional pair is attached to the hindermost segment. The visual organs are a pair of large compound eyes, in addition to which there is frequently a cluster of simple ones. The mouth is provided with a strong pair of chewing jaws, or is adapted for the suction of liquid foods.

The above remarks apply only to the perfect insect or *imago*; for insects, like crustaceans, pass through a series of changes before they finally reach maturity. In many cases they assume three distinct forms—the *larva* or *grub*, the *chrysalis* or *pupa*, and the perfect *imago* already mentioned. The larva is generally a very voracious feeder, growing rapidly, and undergoing a series of *moults* or changes of the skin as the latter becomes too small for its expanding body. When fully grown it ceases to feed, and its next moult leaves it in the form of a pupa, in which state the insect is often quiescent, taking no food for a period varying from a few days to many months. At the appointed time, however, the pupal skin bursts, and the perfect insect emerges. In some insects these metamorphoses are not well marked, and in others there are no such changes at all.

The various phases of insect life form such a marked feature of the natural history of our ponds and streams, that it will be advisable here to give a short description of the different orders of this class, that we may realise to what extent they enter into the scope of our present work. In so doing we shall begin with the lowest forms, and end with the most highly organised and intelligent division.

Order 1. *Rhynchota* or *Hemiptera.*—The insects of this order do not undergo any distinct metamorphoses, hardly any difference being observable between the young and the mature. Most of them have mouths adapted for suction, and some are provided with needle-like organs by which they pierce the bodies of the creatures on which they feed. The order includes wingless parasites such as lice and bugs, also *aphides* or plant lice, which are often winged. The aquatic species include the water gnats, boatmen, and water scorpions of our ponds and streams.

Fig. 16.—A Water Bug (*Corixa Geoffroyi*), twice natural size

Order 2—*Thysanura*—contains the little sugar lice and the springtails, which leap vigorously by means of a pair of elastic bristles at the tip of the abdomen. Nearly all are terrestrial in their habits, and most of them live under the cover of stones, dead leaves and moss, or in dark outhouses and cellars. Their metamorphoses are not complete.

Order 3. *Orthoptera.*—There is a great diversity of opinion as to the extent of this order. It is always made to comprise the cockroaches, crickets, and grasshoppers. Earwigs are also included by some, while others place these in a separate order (*Euplexoptera*) by themselves; and even the dragon flies are sometimes placed with the *Orthoptera*, or straight-winged insects. The chief characteristic of the order is the structure of the wings. The front pair are horny or parchment-like, and the hind pair are folded beneath them, when not in use, something after the manner of a fan. We shall consider the dragon flies as belonging to the next order, and thus there are no aquatic *Orthoptera* for our consideration.

Order 4.—The *Neuroptera*, or nerve-winged insects, are distinguished by two pairs of wings, each wing consisting of a very thin and transparent membrane, supported by a fine network of delicate nervures. The hind wings are sometimes folded as in the *Orthoptera*. The metamorphoses are complete; and in many instances the pupa is quiescent. All are provided with horizontal jaws for chewing in the larval state, but in the perfect state the organs of the mouth are sometimes rudimentary, so that the insect has no power of taking food of any kind. The order includes snake flies, scorpion flies, dragon flies, may flies, and stone flies. The last three of these spend the greater part of their existence in ponds or streams.

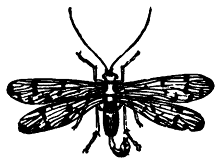


FIG. 17.—SCORPION FLY

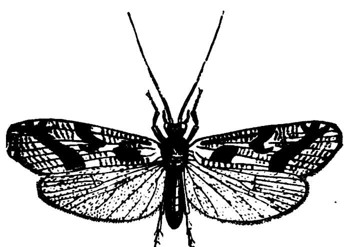


FIG. 18.—CADDIS FLY (*Phryganea minor*), TWICE NATURAL SIZE

FIG. 19.—THE DRONE FLY (*Eristalis tenax*), ONE OF THE *Diptera*, SLIGHTLY ENLARGED

Order 5. *Trichoptera*.—This order comprises the caddis flies, and is so named because the wings of these insects are clothed with hair. The larvæ and pupæ are aquatic, and live in cases which they construct of materials that they find in the water.

Order 6. *Diptera.*—The *Diptera*, or two-winged insects, include a host of species, the larvæ of which have no legs. The house fly and the bluebottle are very familiar examples; and gnats and some others are aquatic during their earlier stages. Fleas are sometimes included in this division, but their wings are only rudimentary.

FIG. 20.—A MOTH WITH AQUATIC LARVA (*Hydrocampa stagnalis*)

Order 7.—The *Lepidoptera*, or scaly-winged insects, comprise many hundreds of species, commonly known as butterflies and moths. A few are aquatic in the larval stage, and will therefore be considered in their place.

Order 8. *Coleoptera*, or horny-winged insects.—These are popularly known as beetles. Their outer wings are hard and of a horny character, and the hind pair, which are membranous, are folded beneath these. Several species spend a portion or the whole of their existence in water.

Order 9. *Hymenoptera*, or membrane-winged insects.—Very few of these are of aquatic habits. They have four membranous

FIG. 21.—AN AQUATIC BEETLE (*Agabus biguttatus*), THREE TIMES NATURAL SIZE

FIG. 22.—A HYMENOPTEROUS INSECT (SAW FLY), ENLARGED

wings, supported by only a few nervures. The mouth is provided with strong mandibles for chewing, as well as a tube for suction. The most familiar examples are ants, bees, and wasps, all of which, and especially the first named, are remarkable for the degree of intelligence they display.

We now reach the last group—the *Vertebrata*—which differs in many important particulars from all the preceding. The main characteristic is that implied by the name—the presence of a back-bone or vertebral column. In some of the lower species, which may be looked upon as connecting links between this division and the higher invertebrates, the vertebral column is not of true bone, but consists of gristle, and is the only representative of what, in higher forms, constitutes the main axis of a complicated and highly-developed internal bony skeleton.

The backbone generally consists of a number of separate bones, all jointed together into a hollow column, through which runs the great nerve called the spinal cord. This cord is continuous with the brain, which is usually enclosed in a bony skull. And here we observe one of the very important distinguishing features between the vertebrates and the higher invertebrates, for while in the former the great axis of the nervous system lies in a bony canal close to the dorsal surface of the body, and the large body cavity containing the organs of digestion and circulation lies in front of or below it, in the latter the chain of nerve masses lies along the front or lower part of the body, in the visceral cavity itself. And, again, while in the vertebrates the limbs (which are never more than four in number) are usually directed *towards* the visceral cavity, in the arthropods they are directed *from* it. Another interesting difference lies in the arrangement of the jaws, which work horizontally in the arthropods and in a vertical plane in the vertebrates.

The vertebrates are divided into five classes—*Pisces* (fishes), *Reptilia* (reptiles), *Amphibia* (amphibians), *Aves* (birds), and *Mammalia* (mammals).

As regards the fishes, the freshwater species alone are so numerous that it would be impossible to deal with all of them satisfactorily in the space at our disposal, so we shall confine our attention to a few of the smaller ones that are suitable for the aquarium.

None of the few British reptiles is really aquatic, but the species of amphibians (frogs, toads, and newts) are so few that we shall describe them all.

Many of our birds and mammals are aquatic in their habits, but the former have already been ably dealt with in a recent volume of this series, and the latter are to be considered in a forthcoming work.

CHAPTER II

ON COLLECTING IN PONDS AND STREAMS

Having now become acquainted with the broad principles of the classification of animal life, we must direct our attention particularly to the study of those living beings that form the population of our ponds and streams, and to this end we make preparations for an excursion to the neighbouring standing and running waters in order that we may watch the habits of the creatures in their haunts, and secure such as may be desired for further observation and study during our leisure hours at home.

The appliances required for this work are of a very simple character, and will not present any great difficulty in the manufacture to those who would prefer to make their own, and it will hardly be necessary to state that every requisite may be obtained with a minimum expenditure of time and trouble by those who prefer to purchase them from the dealers in such commodities.

In the present chapter we shall deal only with the apparatus for use in the collection of those forms of life that are of such a size as to render the use of the lens or microscope unnecessary except for the purpose of discerning details of structure or of closely studying certain movements, which work, by the way, will be better done at home; and then we shall, as a matter of convenience, devote the following chapter especially to the smaller species. With this explanation we will proceed to enumerate and describe the requirements for general work.

These are: (1) a net for capturing insects on the wing; (2) a strong net for catching the inhabitants of the water; (3) a scoop or scraper; (4) a dredge for collecting the aquatic animals that live on the bottom; (5) a bait-can for the conveyance of pond weeds and of live specimens that require more or less water during transit; (6) a number of chip and pill boxes to be carried in a satchel or one or two large pockets; and (7) a walking stick.

We fancy we see the look of astonishment on the face of the reader as he runs down this rather long list of items, and imagines himself, in heavy waterproof boots, disfigured with bulging coat pockets, and laden like a beast of burden with all these articles of luggage; and when we further inform him that he *may* also furnish himself with a rod and line, a supply of hooks, and a box of bait, we can picture his growing disinclination to take up the study of the animal life of our ponds and streams.

But did we say that *all* this paraphernalia would be required on each of his excursions? No, certainly not. In fact, he will find it far more convenient, as a rule, to restrict his modes of procedure,

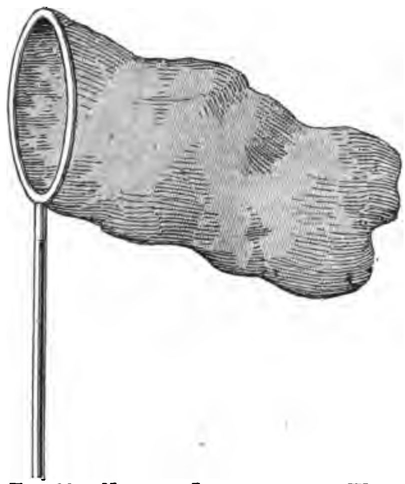


FIG. 23.—NET FOR INSECTS ON THE WING

and to visit favourable spots a second, and, perhaps, more times in order to carry out those methods of attack that were unattempted or only partly worked on the first visit. Thus, it will generally be advisable to fix a day for dredging only; and on another occasion, when the angling rod is brought into requisition, not to attempt much other work. But these are matters to be left in the hands of the operator, and to be regulated according to his powers of endurance and other circumstances. But to return to the apparatus for outdoor work.

First, the nets. One is the ordinary kind used by lepidopterists for the capture of butterflies and moths. It consists of a deep leno bag, with no corners, sewn to a strip of calico that covers a light ring of wire or cane, which is fixed by means of a ferrule to the end of a walking stick. This will be required for securing dragon flies, caddis flies, &c.; also those few species of moths that frequent ponds, and whose larvæ feed on aquatic plants.

The second net must be much stronger, for it has to withstand the friction against dense masses of weeds and the bottoms of ponds

FIG. 24.—POND NET

and ditches. The ring must be of stout wire, and the bag, which must not be deep, of book muslin. It need not be large, a diameter of about nine inches being sufficient, but must be mounted on a strong stick.

Even this net will sometimes show early signs of hard wear, and it is often advisable to use a metal scraper or scoop for the rougher work among pond weeds and the herbage of banks; and this appliance has the additional advantage that its bare rim will readily remove those creatures that stick fast to the under surfaces of aquatic plants, and which would be passed over by the rounded and

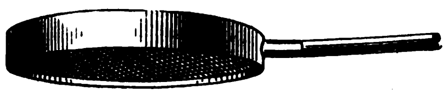


FIG. 25.—THE SCOOP OR SCRAPER

covered ring of the net. It may be made of a hoop of sheet zinc, about two inches wide, with a bottom of fine gauze, and with a ferrule to receive the stick.

The dredge is necessary in order to secure those larvæ and molluscs that live in or on the mud at the bottom, or that attach themselves to stones in the beds of streams. Of course some of these may be secured by means of the pond net if it be well scraped along the bottom, but this is useless in the case of those species that lie at the bottom of rather deep water, and of the larger molluscs that are to be found in large ponds at some distance from the banks. I have seen dredges of a circular form, just like the ordinary pond net, but with a heavier ring; this, however, is hardly satisfactory, since only a small portion of the circumference of the ring can play

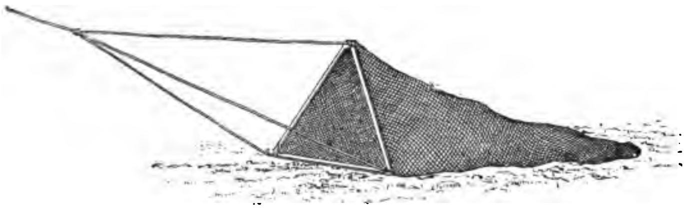


Fig. 26.—The Triangular Dredge

on the bed of the pond or stream. A triangular dredge (fig. 26) is very much better, for as it is pulled over the bottom it naturally settles on one of its sides, and thus covers considerable ground. An oblong form (fig. 27) is also very good, and this may be attached to the line either by three strings—one at each end of one side, and another at the middle of the opposite side—or by four—one at each corner.

The weight of the dredge is a matter for consideration, and must vary according to the nature of the pond or stream to be worked.

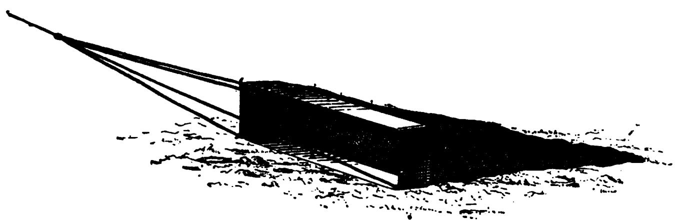


Fig. 27.—The Oblong Dredge

If it is to play over a bed of soft mud where there are but few light weeds to intercept its path, then the frame need not be very heavy; but if it is required for work on a stony bottom or among dense herbage the weight must be increased. Thus it will be necessary to supply oneself with one or two weights that may be readily attached or removed according to the varying circumstances. I know of nothing to answer this purpose so well as a few pieces of lead or 'compo' pipe that have been sawn through longitudinally on one side. These are easily opened and closed, and may be readily placed over the frame of the dredge when required, and as readily removed when a lesser weight is advantageous.

A dredging *hook* is exceedingly useful at times. Large aquatic plants and dense masses of weed that harbour water snails and other creatures, and which are too firmly rooted to be pulled in by the dredge, may often be easily secured with a hook. Some form of this implement is, I believe, to be obtained from the dealers in naturalists' requisites; but a very satisfactory one may be easily made as follows: Procure three ordinary galvanised meat-hooks from the ironmonger. These are hooked at both ends. Straighten out one end of each, and bind all three together with many turns of stout copper wire, leaving a double or treble loop of the wire at the straight end to take the string. Then, if you know just a little of the tinman's art, strengthen the whole by running a little solder between the coils.

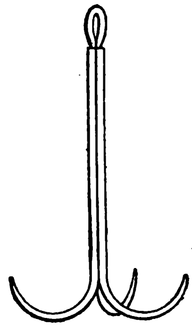


Fig. 28.—The Dredging Hook

The bait-can need hardly be described, as everybody must be familiar with it; and, in a case of emergency, there will never be any difficulty in procuring a convenient substitute.

The chip boxes will be exceedingly useful, indeed almost indispensable, for the conveyance of the smaller and more delicate shells, and for small creatures of any kind that may be carried home alive without water. A good supply of these should always be at hand, as well as a number of glass-bottomed pill boxes of various sizes for the accommodation of the winged insects that are caught with the net.

If it is intended to capture fishes the outfit must be arranged according to the nature of the specimens sought and the use to be made of them. Many small species for the aquarium may be easily caught with a net, and so may young specimens of the larger kinds. A strong net well worked among the weeds of ponds and small streams or along weedy banks of rivers will supply you with many captives, and a dredge pulled rapidly along the beds will 'bag' bottom fish such as the loach and the gudgeon; and if these are to be taken home alive the can must be large enough to accommodate them with comfort and to hold sufficient water to supply them with oxygen for respiration during the homeward journey.

The larger fishes and those that inhabit deep water are to be taken only by means of the hook, and as such will generally be required for immediate study or to preserve for a permanent collection, there will be no need for the can.

Information respecting the habits of some species, such as will be likely to add to the success of the collector, will be given in the chapter devoted especially to the study of the fishes of our ponds and streams.

All specimens taken home alive must of course be removed from their confined quarters as soon as possible after your return; and to this end it is advisable always to have suitable accommodations quite ready for them before the start is made. Large and expensive glass aquaria are not at all necessary for this purpose, but for the help of those who desire to do the thing in style, full directions will be found in the fourth chapter respecting the construction stocking, and management of permanent aquaria.

It would be quite a mistake, however, to suppose that such aquaria have even the slightest advantage over the rudest extempore accommodation that may be provided out of the utensils to be found in every household, at least to the aquatic creatures themselves; and the only benefits to the owner are the possibly ornamental character of the aquatic home and the greater facilities for observation. Indeed, we shall have to learn that the ruder accommodation afforded by tubs, pans, jars, &c. are really better for our captives, being more in accordance with the character of their natural haunts and, consequently, more in harmony with their habits and likings.

This being the case, we ought to have no difficulty whatever in providing a very satisfactory series of utensils, properly supplied with gravel and fresh water, before starting on the tour of collection.

Nothing is better than a commodious tub for fish, frog spawn, tadpoles, newts, &c.; bearing in mind the necessity for a second similar utensil if among the captives there are those which would prey on others. Aquatic molluscs, crustaceans, spiders, and insects will always do well in earthenware pans or small wooden tubs, attention being paid to the precaution just mentioned. All the small species—such as the small molluscs, larvæ of insects, water beetles—and all the lower forms of aquatic creatures may be placed in jars of convenient sizes, glass jars being employed for all minute creatures as well as for those whose habits and structure are to be the subject of close and immediate study.

So much, then, for the appliances for and the preparations preceding the hunt. Next let us briefly consider the two problems 'When?' and 'Where?'

The former question is easily answered; for, although it may be sometimes necessary to consult the season when a special expedition is to be made in search of some particular species, the hunter of ponds and streams is sure to find *something* of interest at any season of the year, the only barrier in his way being the thick covering of ice that forms in the occasional event of a prolonged frost. Every month of the year will supply material for an enthusiastic observer; and while during the three genial seasons—spring, summer, and autumn—fresh water is everywhere teeming with varied forms of life, the bleaker months of winter will always yield more than sufficient to satisfy the most ambitious lover of Nature. Many a time have I been agreeably astonished at the results of a few hours' work on a mild day in December, January, or February, and have had the satisfaction of knowing that my boxes and other utensils were all well stocked with the fruits of my labour. Even when the water itself has seemed almost devoid of life, a small dredge and a 'scraper' have often been the means of securing abundance of living beings from hidden weeds and a muddy bed.

The second question—'Where?'—is disposed of almost as easily as the first. Where shall we *not* try our luck? Here is the difficulty—if difficulty it can be called—to find a pond or stream, large or small, that has nothing to yield. The tyro will probably find his labours well repaid if he travels no further than the nearest of the neighbouring ponds and ditches; and it is not until he has made himself fairly well acquainted with the very common forms of aquatic life that he will find much advantage in rambling to distant spots in search of the rarer and more local species.

Still there are ponds and ponds, and streams and streams; some literally swarming with life of all kinds, and others almost barren. A pond situated in the shade of a dense wood, and particularly if it is surrounded by tall trees, is not likely to be very productive. The abundance of decomposing vegetable matter, especially in the autumn, renders the water extremely putrid and poisonous, so much so that the first plunge of the net liberates a volume of the most offensive gases; and the feeble light that falls upon the water is no sufficient to support the pond weeds which would absorb the noxious products of decomposition and set free the oxygen necessary for the existence of animal life.

A luxuriance of vegetable growth may generally be regarded as a sure sign of the presence of animal life; and a pond so densely covered with duckweed that the water itself is almost completely hidden from view will often prove a veritable treasury to the collector.

Streams also are very variable in the productiveness of their animal life, but it is rarely that we meet with one that is almost or absolutely unproductive unless it is contaminated by the poisonous drainage of a factory or the refuse resulting from certain mining operations. In manufacturing districts it is not at all uncommon to find a stream that is utilised as a motive power for working the machinery of mills, and which also receives the waste products of certain chemical operations, absolutely lifeless; but even here the smaller streamlets that drain into the main course may be exceedingly productive.

Probably, however, nothing will be gained by occupying space in the discussion of such matters as these, or to attempt to lay down any fixed rules for the collector's guidance, for any one who exercises his observant faculty to a moderate degree will soon become a fair judge of the prospects before him.

And now, having reached the bank of a selected hunting ground, how are our operations to be carried on?

First, then, previous to the attack on the water itself, carefully examine the surroundings. If your search is conducted during the winter months, much may often be learnt by overturning stones and logs of wood, for in this way you may meet with hibernating amphibians and other creatures, and thus become acquainted with their habits at a period during which they are generally neglected. If it is summer time, then never omit an examination of the surrounding foliage, also the surfaces of bare stones, and neighbouring walls, fences, and trunks of trees.

If dragon flies are seen on the wing, get your light net ready for action, and keep it handy by you throughout the hunt. Some of these fly with marvellous rapidity, calling your utmost skill into activity, while others are easily 'bagged.' During very dull weather most of them remain at rest, generally very near the water's edge, and often on reeds and other aquatic plants that stand out above the surface of the pond or stream. At such times the net is frequently unnecessary, for the insects may be easily 'boxed,' or even removed from their hold by taking the wings gently between finger and thumb.

On stones, walls, fences, and trunks of trees in the vicinity of the water, more especially near the banks of running streams, we may meet with other members of the order *Neuroptera*—insects commonly known as stone flies, alder flies, and willow flies. These are, as a rule, very lazy creatures, and may generally be easily taken in pill boxes as they sit. Glass-bottomed boxes are most suitable for this purpose, for they enable you to see the insect after it has been captured, and thus acquaint you with a favourable opportunity of popping on the lid.

Having surveyed the surroundings of the pond or the banks of the stream, examine the outstanding and floating weeds at the water's edge, and the herbage that overhangs the water from the banks. Here you may meet with *Succinea putris* and other molluscs of the same genus, which, though not strictly aquatic, frequent marshes and the banks of ponds and ditches; and, thus coming frequently within the range of the pond-hunter's observations, may reasonably be included among the objects of his search.

Few spectacles are more interesting than the emergence of the perfect insect from its pupal skin, and the collector at work on the banks of ponds will sometimes catch sight of the pupa of a dragon fly, walking up the stem of an aquatic plant in order to undergo its final metamorphoses. Such a sight should never be missed if the opportunity presents itself, and the temporary postponement of your dipping, scraping, and dredging will be well repaid by the instructive lesson afforded by a careful observation of the transformation.

Having thus learnt all you can by a close scrutiny of the water's edge and its vicinity, preparations must be made for the attack on the pond itself; but even in this it is generally a bad policy to dash straight off with the net. First watch the surface of the water and its floating and partially submerged weeds, and catch what you require of those creatures which live principally or entirely on the surface, before the pond is disturbed to any great extent. Some of the creatures to which we refer would either dart to the bottom or scuttle away to the centre of the water beyond your reach if you started with a bold attack; and the water would soon be rendered so muddy that all further observation of the living beings in their haunts would be impossible. If you see any aquatic snails you require, resting on the weeds close to the surface, or crawling, as they frequently do, in an inverted position along the surface film of the water, place a very shallow net gently beneath them and lift them out without disturbing the surroundings. Water gnats (*Hydrodromica*) and whirligig beetles (*Gyrinidæ*)—of each of which there are several species—may be seen sporting in the sun, and these may be taken in the same way, but the net must be brought up smartly against them from below.

Attention must next be given to the hitherto unseen inhabitants of the water, but avoiding, for the present, those which make their home at the bottom. Place the shallow net against submerged plants, and scrape them upward to remove the water snails that adhere to their leaves. If the herbage is very dense, substitute the metal scraper for the ordinary ring-net. By this means you may secure newts and univalve molluscs, together with various larvæ, such as those of the caddis flies, and also the aquatic caterpillars of the china-mark moths (*Hydrocampidæ*) which live in cases of their own construction and feed close to the surface of the water.

Presently we shall learn what is to be done with the various creatures captured—how they are to be conveyed home with the greatest convenience and with due regard to their safety.

Now we make our attack on the bed, and, if this is composed of a soft mud, as is generally the case, we are obliged to abandon all further attempts to keep the water clear and transparent. A deeper net is chosen—one about nine inches or a foot in depth; and, instead of working the net upwards, we may force it well down on the bottom, and scrape it in towards the bank. The first haul will give you some idea as to the force to be employed during this part of your work. If the weeds are so dense that the bottom is not reached at all, then a little more downward pressure must be applied. If, on the other hand, the net is full of soft mud or too heavily laden with sand or gravel, the pressure may be reduced. However, it must be remembered that we are now searching for the creatures that prefer the bottom, including those which live partially or wholly buried in the bed, and that it is therefore absolutely necessary to haul in more or less of the substance in which they reside.

It often happens that the weeds are so dense in ponds and sluggish streams that there is no getting at the bottom with any other than a very strong and rigid net; and, under these circumstances, the dredging hook may prove useful in clearing away some of the excess of vegetation, at the same time bringing abundance of animal life within your reach.

While thus engaged in the search for the denizens of the deep, you will of course land a quantity of weed together with the creatures that lodge thereon ; and this is the time when your hauls will be richest, both as regards quantity and variety of species. So marvellous, indeed, is the yield of some of our ponds and ditches, that two or more persons might find constant employment for the time being in the examination of the material landed and in the selection and boxing of the creatures required.

Always turn out the contents of the net on a piece of bare ground near the water, otherwise some of the most active creatures will soon disappear among the grass.

Having first picked out as much clean weed as you require, and placed this in the can, you may commence the process of selection. As a rule nearly all the larger creatures may be dropped into the can, where they will be pretty safely lodged till your return ; and no water, except the small quantity that drains from the wet weeds, need be taken unless you are including fishes in your captures. Nor will it be necessary to take much pains in the separation of the carnivorous and the more helpless creatures, providing you have *plenty* of space and a large quantity of vegetation, and are not compelled to detain your captives in the collecting can for a lengthened period.

Small molluscs, and indeed all small creatures which you specially value, either because they are rare or because they were previously unknown to you, must be placed separately in small boxes ; chip boxes being used for the molluscs and other creatures that do well for a time without water, and small tins, each containing a little pond-weed, for others (chiefly the soft-bodied animals that have no hardened covering) which must not be allowed to get dry.

It frequently happens that aquatic plants harbour such a host of small molluscs and other little lodgers, that the examination and selection occupy no small amount of time, and in this case, providing you have the accommodation at your disposal, it is a good plan to pack a quantity of the weed into a separate can, and reserve the more careful inspection for your leisure at home.

I have recommended the thorough examination of aquatic plants, but it must not be forgotten that the mud, sand, or gravel removed from the bottom should be searched with equal care. The first-named material is the home of numerous larvæ of beetles and other insects, and often contains small bivalve molluscs (*Sphæriidæ*) which would be overlooked by a careless observer; and the only British species of the *Neritina* genus may often be found attached to the surfaces of stones taken from a gravelly bed.

Although the preceding operations are quite sufficient for the general success of the collector of animal life in fresh water, yet an occasional hour or so with the dredge will be necessary, more especially for the taking of the larger bivalve molluscs (*Unionidæ*) and other inhabitants of large ponds and deep water.

In some cases a small boat is a great aid during the dredging manipulations, but much may be done without its assistance. We have already referred to forms of dredging nets which do not retain their proper position well while in use, and which, if dropped into deep water, may fall on the wrong side. With such dredges, and indeed with any form of dredge, the following *modus operandi* will succeed well whether for ponds of moderate size, the arms of lakes, very large ponds, or even rivers, remembering that two persons can do the work better than one:

Place the dredge on the bank close to and facing the water's edge. Tie a stone of suitable size to the end of a string. Throw the stone to the opposite bank, and then haul the dredge across. By this means you are enabled to work on ground otherwise beyond your reach with the best possible chance of the dredge maintaining its proper position. Should the dredge prove too light for the work, as will probably be the case on a gravelly bottom or where there is a superabundance of weeds, then it must be weighted as already suggested.

During the summer months most ponds are so full of animal life that you will generally land hundreds of creatures of the commoner species which you do not require; and in the case of small ponds especially, if your work as a searcher is well done, you will have considerably reduced the density of the population by the numerous haulings. Now, it is not right that all these harmless creatures that add so much to the beauty, purity (for many of them are very useful scavengers), and usefulness of our ponds should be permanently removed from their element and left on the bank to dry and perish in the sun; and for this reason every thoughtful and humane collector of freshwater life does not mind the trouble of pushing back into the pond the masses of weed and other matter which still teem with life after he has removed all he requires for his own study. The time spent in this act is trifling compared with the good done and the satisfaction obtained, and the act itself soon becomes so habitual that it is accomplished almost involuntarily, so that the doer experiences no feeling of additional labour or any loss of time.

It now remains for us to see what is to be done with all the takings on our return home.

As a rule the miscellaneous contents of the can should receive the first attention, particularly so if it is overcrowded and contains many voracious larvæ. Throw all into a large tub or bath containing water only two or three inches deep, for the selection and sorting of the various creatures will be a matter of considerable time and difficulty if they have an opportunity of hiding at a depth where they are not easily seen.

The aquatic plants required for the aquaria may be set in position at once, after having been examined for creatures which are to have special lodgings consigned to them. Fishes, if any, should generally have the most space. Water beetles and carnivorous larvæ must have an apartment to themselves. Molluscs may be distributed among the various aquaria, large and small, but a special glass jar may be reserved for any species which are to be favoured with a special study. Freshwater shrimps are very useful as scavengers, but do not do so well in still as in running water. And so we arrange the specimens according to the accommodation at our disposal and the direction which our studies and observations are to take.

The larger and more active creatures are best transferred by means of a small net, about four or five inches deep, and this may

FIG. 29.—WIRE SUPPORT FOR THE AQUARIUM NET

be mounted on a single piece of galvanised iron wire bent as shown in fig. 29, so that it forms both ring and handle. Such a net is always useful as an accessory to the aquarium, not only for the transference of living things, but also for the easy removal of the dead.

But it will invariably be found that the contents of the collecting can include a host of creatures that are much too small to be removed with a net. Such are the small larvæ and water beetles little molluscs—both univalve and bivalve—water fleas, cyclops &c., to say nothing of the numerous truly microscopic beings. These are easily removed and transferred to suitable quarters by means of a dipping tube.

This exceedingly useful accessory is simply a straight piece of glass tubing, of about three-sixteenths of an inch internal diameter, and about nine inches long or more, according to the depth of the vessels in which it is to be used. It is employed as follows:

Close the top of the tube firmly with the finger, and then plunge its lower end into the water till it is immediately above the object desired. Then remove the finger, and the water will suddenly rush up the tube, carrying the object with it. Close the top again, and you may then withdraw the tube without losing any of its contents, which may be allowed to run out again by admitting air at the top. Even small molluscs and other objects heavier than water may be transferred in this way, but, when dealing with these, it will be necessary to withdraw the tube before they have had time to sink to the bottom again.

FIG. 30.—METHOD OF USING THE DIPPING TUBE

The dipping tube is also useful for removing drops of water for examination under the microscope, but this is a matter for consideration in our next chapter.

We have not yet referred to the specimens brought home in small boxes. Most of these will probably be objects obtained from the water, and may be replaced in their native element according to the convenience or the desires of the collector; but they may often include winged insects, such as caddis flies, stone flies, dragon flies, &c. These may be turned out into any kind of vessel—a large bell-jar, a propagating glass, a fern case, or even a conservatory—where their movements may be watched while they live; and, when dead, they may be set for a permanent collection according to the instructions given in a subsequent chapter (Chapter IV).

Few collectors of pond and river life would contentedly neglect the interesting study of the infinitely small, yet there may be many who cannot afford the luxury of a really good compound microscope; so, in our endeavour to satisfy the demands of the majority of beginners, we shall, in our next chapter, deal with the collection of the minute forms of aquatic life, and the manipulation of an inexpensive magnifier such as will probably come within the reach of almost everybody.

CHAPTER III

THE COLLECTING OF MINUTE FORMS OF LIFE. THE USE OF THE MICROSCOPE

THE methods of collecting and examining the lower and minute forms of animal life are so different from those already described for the larger species, that it is more convenient to deal with them separately; so we shall devote the present chapter exclusively to this interesting portion of the pond-hunter's work; and, following the plan of the preceding pages, we shall first enumerate and describe the apparatus for the work in the field.

The ordinary pond net is, of course, absolutely useless in this case, for the minute creatures required readily pass through the meshes of the gauze; but a very small net, two or three inches in diameter, and made of the finest muslin, is often useful for lifting out small weeds to which many of the lower forms attach themselves.

Our chief work now consists in securing the numerous little animals which move freely in the water, or which attach themselves to small floating or submerged objects, and these are readily obtained by simply taking samples of the water itself, together with the small particles of matter that give a foothold to the less active creatures.

This object is most conveniently attained by means of several little bottles or tubes, fitted with corks. These can be easily fixed in succession on the end of a stick.

Little tubular bottles, two or three inches long, are best suited for the purpose. A spring clip, capable of holding them firmly, is fastened on the end of a walking stick; and by this means a succession of dips may be made in the various ponds and ditches visited.

It may be asked, 'Why not put all the samples taken into one large bottle instead of into a number of small ones?' But it will be readily seen that the isolation of the different samples taken will enable us to compare the productiveness and peculiarities of the different pieces of water examined, so that on future visits to the same neighbourhood we know just where to go for particular forms of life. And in order to further assist us in becoming familiar with the habitats of the more interesting forms, we should always place

FIG. 31.—DIPPING BOTTLE AND CLIP

a blank label on each bottle, so that the samples collected may be marked with the nature of the piece of water from which they were taken, together with any other memoranda of interest or importance.

Although we are now dealing with what is generally spoken of as microscopic life, yet it must be remembered that many of the animals included under this head are distinctly visible to the naked eye, and others are easily rendered visible by means of a pocket magnifying lens. This being the case, we can often form some rough estimate of the amount of life in any collected sample by a cursory examination in the field; and to this end we include a pocket magnifier in our outfit.

The 'Coddington' and the 'triplet' lenses are both useful for this purpose. I have also found the focussing-glass serve extremely well for the examination of the samples of water collected, when combining the photographic study of natural objects with a little pond-searching during the same outing.

It frequently happens that the contents of each bottle include much less of animal life than we should like to transmit by it—

perhaps only a few visible forms of species of which we should like a considerable stock for future experiment and observation. In this case a small strainer is useful for the purpose of concentrating a larger number of living things in a given quantity of water.

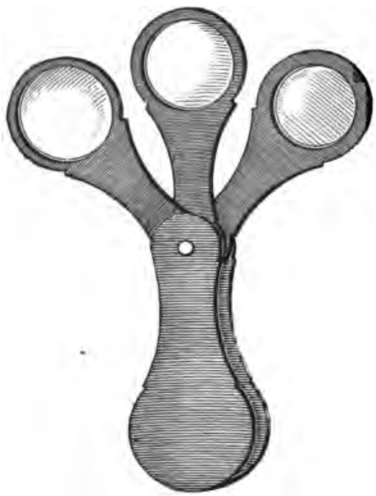


FIG. 32.—THE 'TRIPLET' LENS

The reader will probably be sufficiently ingenious to design and construct a simple piece of apparatus for this purpose from materials ready at hand, but for the help of those of a less inventive turn, a figure and brief description of one that has done good service follows.

It consists of a wide-mouthed bottle, fitted with a good cork, through the centre of which passes an ordinary tin funnel. Two or more large holes are bored in the cork in addition to the one which receives the funnel, and these are all covered below by means of a piece of the finest muslin.

It will now be seen that if water be poured into the funnel beyond the capacity of the bottle, the excess will pass through the muslin and escape through the cork. Thus any quantity of water may be strained, and the residue, rich in animal life, may then be transferred to bottles or tubes of a convenient size for transmission in the pocket.

I need hardly say that the very minute animals will pass readily through the finest material obtainable. But a great variety of living beings may be encompassed in a small space by means of the strainer; and a considerable number of the minutest forms even may also be concentrated in the same way, for many of them remain attached to pieces of weed and particles of miscellaneous matter that will not pass through the holes in the muslin.

One other hint I should like to give before closing our short account of the few appliances required for this portion of the pond-hunter's work There are times when business or other circumstances prevent a run to the fields, when, at the same time, a few odd moments now and again could be spared for the observation of specimens previously collected. Then, to prevent disappointment in this matter, why not have a pond—a collecting ground teeming with all kinds of microscopic animal life—at home?


FIG. 33.—THE STRAINER

The establishment of such a 'stock' is easy in the extreme. Take a dipping bottle and stick, strainer, and bait-can. Collect samples of water from every pond and ditch you meet with. Pass all through the strainer; and as often as the strainer shows signs of a great density of population, throw its contents into the bait-can.

In this way you soon obtain a quart or so of water containing thousands of living forms in every inch. Take this home, throw it into any large vessel that will answer the purposes of an aquarium, and then dilute with clear water.

Here, then, is your pond. At any time, and in a manner to be presently described, you may remove a drop of water for microscopic examination, or secure any particular little creature you may observe with or without the aid of a lens.

In our chapter on the aquarium there are the necessary instructions for the aëration of the water and the prevention of putrefaction; and if a little attention be paid to these matters your 'stock' will keep in good condition for a very long time; in fact, there is no reason whatever why many of the animals should not continue their successions of generations for years, with no trouble on the part of the owner save the occasional addition of a little water to replace that lost by evaporation.

While speaking of the requisites for field work, some hints were given concerning their uses in the field; but we must now apply ourselves particularly for a short time to the out-of-door operations.

Microscopic life is to be found in ponds and streams all the year round. On the coldest days of December and January, even when ice covers the surface of the water, living beings are more or less active. But the harvest time of the collector is undoubtedly the summer months.

As a rule the microscopist need not travel far in search of game. Almost every permanent pond and ditch, however small, teems with life; and even a few minutes spent in collecting the casual visitors of the waterbutt will often yield specimens that may profitably be studied for weeks. But occasionally it will be necessary to pay visits to distant waters in order to collect certain specimens that are not to be taken nearer home, for the microscopic as well as the higher life includes local species, which thrive better on certain soils than on others, or which are to be found exclusively or almost so on certain species of aquatic plants.

It will always be noticed, however, that certain pieces of water are far more productive than others, even in the same immediate neighbourhood; and the general outward appearance of the best hunting grounds will soon become familiar to the worker.

Very little microscopic life is to be found in streams, more especially the rapid ones. Very sluggish streams, particularly those of small size, yield more. But ditches and ponds are literally full of life, even to the narrowest and smallest puddles.

You take a dip from the water of each pool or ditch visited, examine it carefully by holding it up to the light and looking into it through the lens. If it shows signs of life—such life as you are requiring—cork the bottle and place it in your pocket reserved for the samples, with, of course, some provision for preventing the bottles from clashing together and breaking.

Such samples as give only a little evidence of life, yet of a kind required at the time, may be passed through the strainer as above directed; and little fragments of pond weeds and *débris* that find their way into the dipping bottles and strainer should always be retained for the examination and study of such specimens as may be attached to them. It should also be known that many microscopic animals live almost exclusively on or in the mud at the bottom of ponds and ditches; hence it is necessary to take home some of this sediment, which may generally be most conveniently scooped up from the margins.

Should you happen to meet with a pond or ditch exceptionally rich in microscopic life, and also happen to have your pond net and can with you, by all means embrace the opportunity of laying in a stock from which you can obtain interesting objects to occupy your spare moments at home. In this case there will be no need to burden yourself with any large quantity of water, but simply place in the can several clumps of pond weeds, always including, when possible, a good supply of duckweed. Myriads of little beings will be hauled in with the vegetable matter thus secured, some attached to the leaves, stems, and rootlets, and others free in the water that adheres to the entangled masses of weeds. To this, of course, may be added any samples of water which show abundant signs of animal life.

As soon as possible after your return you must give some attention to the takings. The corks of the bottles or tubes should be removed at once, in order that the little animals may not be killed through a deficiency of air. Then set before you a number of glass jars, and throw into them the contents of the bottles, isolating the takings from each separate pond or ditch as far as you think desirable. Add some ordinary water to each of the samples, and then put into each jar a little of any kind of pond weed. The weed will aërate the water, and thus keep the contents of the jars in good condition for a considerable time.

Then, as regards the contents of the can, throw them all out into any large vessel—jar, pan, or any other suitable receptacle, add plenty of water, and then set it aside in a cool place out of the way of the direct rays of the sun.

There is much to interest one in the movements of some of the larger of the so-called microscopic creatures, even when viewed without the assistance of any kind of magnifier; but the details of these movements, as well as the structure and development of the minute beings, are not to be observed without the aid of a microscope; and since this instrument is absolutely indispensable to any one who intends to study the lower forms of aquatic life, we shall now deal briefly with the methods of using it as far as they are likely to be of service to beginners in this department of natural history.

Microscopes are of two kinds—simple and compound. The simple microscope is merely a magnifying lens or a combination of lenses mounted on some kind of support. It is, in fact, merely a magnifying lens such as we have recommended for field work, with the addition of a stage on which to place the objects that are to be examined, and perhaps also a mirror by means of which light may be reflected through transparent objects.

One of the best forms of this instrument is represented in fig. 34, in which the eyepiece, *m*, carrying the convex lens, is fixed on a horizontal support, E. The stage, *b*, is perforated at its centre, so that light reflected upwards by the mirror, M, may be made to pass through transparent objects supported on it; and the distance between the lens and the object may be adjusted by means of the rackwork, K, and the screw, D.

A great number of very interesting movements and structures that are not to be observed with the unaided eye, may be witnessed through the simple microscope; but this instrument, although useful at times even to an advanced student of microscopic life, is of no use in the study of the more minute forms.

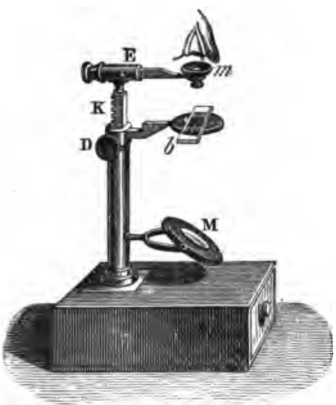


FIG. 34.—A SIMPLE MICROSCOPE

It is absolutely essential, therefore, that those who intend to make microscopic life a study should have a compound microscope that will magnify to at least three or four hundred diameters.

I do not want to discourage beginners by counting over the cost of such an instrument as I would recommend; but I must say at once that a really useful microscope for general work cannot be obtained under four or five pounds.

It is well to remember, however, that the amount of work that can be done is about proportional to the quality of the instrument used—that a little may be done with the aid of a really cheap instrument, more still with a better one, and the most advanced work with the best appliances. This being the case, there is no reason whatever why the young student of pond life should not at first secure the best instrument and accessories which his funds permit, and then settle down cheerfully to do the best work he can with whatever he is fortunate enough to secure.

When a youngster, I myself found that much pleasure and profit could be obtained by the use of a little microscope similar to that figured on page 37, and which cost only about fifteen shillings. It had only one eyepiece; and the three lenses, called the objectives, fitted at the bottom of the tube, could be used singly or combined, thus giving the different 'powers' required for different classes of objects. It had also a reflector—a rotating mirror beneath the stage, by means of which the light could be reflected upwards. Such microscopes are readily obtained; and, although far behind the requirements of the student, are certainly preferable to no microscope at all.

More useful instruments are sold under such names as 'The Student's Microscope,' 'The College Microscope,' 'The School Microscope,' &c.; generally ranging in price from about fifty shillings to twice that sum. The price includes one, and sometimes two eyepieces; also two objectives, and often one or two minor accessories.

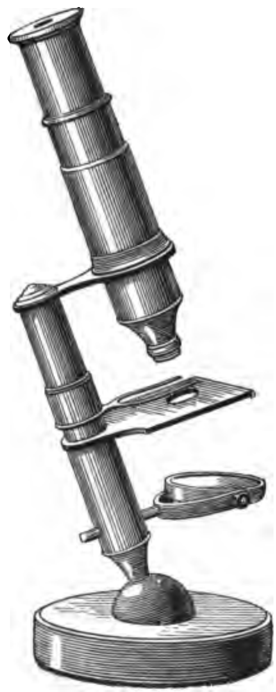


FIG. 35.—A CHEAP FORM OF COMPOUND MICROSCOPE

The purchaser of a microscope is often allowed a choice of objectives, and this is certainly a great convenience, for the powers suitable for the work of certain persons might not be at all adapted to that of others. The most useful objectives for the study of pond life are the 2-inch, 1-inch, ½-inch, and ¼-inch; and, where the purchaser is limited to two, preference should be given to the 1-inch and the ¼-inch.

These objectives or object glasses are named according to their focal distances, and those of longer focus have the lowest magnifying power.

It is not possible to give here the magnifying powers of the different lenses, for they will vary with the instrument and the manner in which it is used; but it will be seen that, with two eyepieces and two objectives, four combinations, and hence four different powers, can be employed. Again, an increase in magnifying power can also be made by drawing out the sliding tube of the microscope without making any change in the lenses; but the increase in the dimensions of the image brought about by this means is generally obtained at a considerable expense as far as clearness of definition is concerned.

FIG. 36.—THE STUDENT'S MICROSCOPE

A 'condenser' is often supplied with a good compound microscope, sometimes fixed, and sometimes supported on a separate adjustable stand. It is a convex lens of short focus, the use of which is to converge the light passing through it so that it may be concentrated on a small object.

It may be placed between the reflector and the object on the stage, so that a very powerful light may be sent *through* the latter; or it may be used to concentrate the rays of light from a higher level down on to the top of an opaque object. But it is not likely to be of very much service used in either of these ways, for the light thrown up by the mirror is usually quite strong enough for transparent objects, and the pond-hunter has but little to do with opaque ones.

Nevertheless the reader should procure one of these lenses, for he can easily convert it into what is known as a 'spot lens' for the examination of transparent objects over a black background. To do this, cut out a piece of black paper just large enough to cover

FIG. 37.—SECTION OF THE SPOT LENS

the flat side of the lens, and then from the middle of this a circle, three-quarters of an inch in diameter, being careful to have a clean edge. Gum this on the flat side of the condenser, and then fix a circular piece of the same paper, half an inch in diameter, in the middle of the clear space left, thus leaving only a ring of the glass an eighth of an inch wide, uncovered.

If this lens is now placed between the reflector and the stage, and at a suitable distance from the transparent object to be examined, light thrown on it from below will be converged on the object through the clear ring of glass, while the black background, formed by the central black spot behind it, will enable the details of structure to be seen distinctly.

We have now to consider the several little appliances required in conjunction with the microscope. These are glass slips, cover glasses, cells, live-box, zoophyte trough, watch glasses, glass jars, dipping tubes, forceps, scissors, needles, scalpels, &c.

The glass slips generally employed measure three inches long and one wide, and are ground at the edges; and the cover glasses are very thin circular or square pieces of various sizes.

Unless the reader intends to mount permanent specimens for the microscope, he will find about a dozen glass slips quite sufficient for his purpose. And, as regards the cover glasses, a quarter of an ounce of circles, mixed sizes, will answer all requirements for some time.

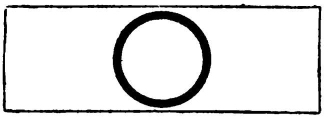


Fig. 38.—Cell on Glass Slip

The cells are simply rings of some suitable material, of the same size as the cover glasses, cemented to the slip. A cell is necessary when the cover glass has to be raised in order to avoid pressure on a small object, or to give sufficient space between the two glasses to accommodate an object of larger size.

Microscopists generally make their own cells, either by cementing rings of glass, ivory, ebonite, or other material on the slips; or, when a very shallow cell is required, by placing the slip on a turntable, and making a ring of a quick-drying cement. The rings used can be purchased; but perhaps it is better for a beginner to buy a few cells of different diameters and varying depths ready made.

A live-box is often supplied with the microscope. This and the zoophyte trough are really cells of a larger size, suitable for the observation of the movements and development of living objects.

Watch glasses are exceedingly convenient for the isolation and preliminary observation of small quantities of pond water. They may be bought at the rate of about sixpence a dozen.

Almost any kind of glass jar may be used to contain specimens of water in which the microscopic animals are to be stored, but the best for the purpose are those which are flanged at the top and have ground edges. Ground glass discs are also useful as covers to keep out the dust.

The simplest form of dipping tube is merely a piece of glass tubing, of about a quarter of an inch internal diameter, eight or nine inches long, with the edges smoothed; but it is convenient to have at least one tapered off at one end. They are easily made as follows:

Procure a three-foot length of glass tubing of the size named, and cut it into three pieces, one eighteen inches and two nine inches long. To cut the tubing, give a sharp stroke with a small triangular file, and then pull the two parts asunder, slightly bending the tube from the side of the file-cut.

Let the ends of the two nine-inch pieces just touch the outside of a gas flame for a few seconds, and the edges will be softened by the heat, and become perfectly smooth. Thus two plain dipping tubes are completed.

Now take the eighteen-inch length, and heat it in an ordinary gas flame, holding it the broad way of the flame, and turning it round and round that it may become equally heated on all sides.

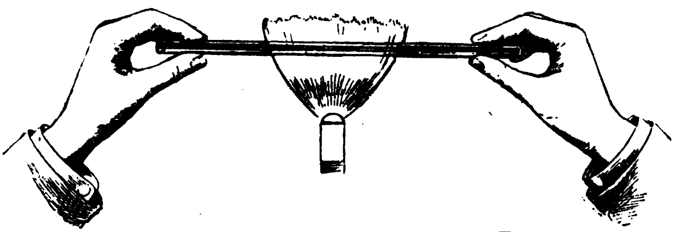


FIG. 39.—SHOWING HOW TO SOFTEN GLASS TUBING

When it is so soft that it easily bends by its own weight, take it out of the flame, and pull the two halves very slowly in a perfectly straight line till the diameter in the smallest part is reduced to about one-half or rather less. Continue to hold it in this position till the glass has become rigid, and then set it aside to cool.

When cold, cut the tube into two where the diameter is smallest, and then cut one piece at a point where the diameter is intermediate between the largest and the smallest. Thus two dipping

FIG. 40.—SHOWING WHERE TO CUT THE TUBE IN ORDER TO GET TWO DIPPING TUBES WITH DIFFERENT APERTURES

tubes are obtained, with their smaller ends of different sizes. Both small and large ends should now be smoothed in the gas flame as recommended for the straight tubes.

The forceps, we need hardly say, are used to pick up and to hold very small objects. The needles answer the same purpose, and these are so frequently of service, and so inexpensive withal, that the young microscopist should never be without them. They should always be mounted in small wooden handles, which can be readily done by pushing the eyes into little pieces of twig; and one or two might, with advantage, have their points bent, while others may be ground on a hone till their points are flat and sharp.

The scissors should be very pointed, and must cut well quite to the point. If the reader desires to have the best appliances in this respect, he had better purchase two pairs of small dissecting scissors—one with straight and the other with bent blades.

The other item mentioned in our list is the scalpels or dissecting knives. The well-sharpened blades of an ordinary pocket knife may be made to answer all the purposes of these; still, where much practical work is anticipated, it will be as well to procure a case of scalpels, and such cases generally contain, in addition to the knives, a pair of forceps and one or two pairs of dissecting scissors.

Before commencing the examination of the collected specimens of pond life, always make it a rule to have every appliance that may *possibly* be required ready at hand. Then, by means of a dipping tube, small quantities of water may be removed from the jars or bottles, and little objects visible to the naked eye or with the aid of a lens may be selected and transferred.

If it is simply desired to remove a drop or so of the water, immerse the dipping tube into the jar, and then close the upper end with the forefinger and withdraw it. As long as the top of the tube is closed so firmly that air cannot enter, the water will not flow out; but if the pressure of the finger be very gradually released, the water will sink so slowly that single drops and even smaller quantities may be transferred to glass slips for examination.

Sometimes it may be required to isolate a portion of the water and sediment at the bottom of a jar, or to remove some one particular animal that is seen swimming about in it. To do this, close the top of the dipping tube firmly, previous to plunging it into the water, and when the lower end is exactly over and close to the thing wanted, open the top of the tube, and the water will immediately rush into it, carrying with it just what you require. When dealing with very small objects, and in other cases where it is advisable to withdraw and transfer only very small quantities of the water, one of the dipping tubes with reduced apertures should be used.

A careful observer will soon discover that very interesting and instructive movements of aquatic animals may be watched with the aid of a hand lens as the creatures swim about in the glass jars, or as they creep over the glass itself. But it is often impossible to follow the little animals as they move rapidly about in the liberal space provided them, so we secure them in a dipping tube and transfer them to a watch glass or into the zoophyte trough, where they are more conveniently watched either with a hand lens or under the low powers of the compound microscope.

The very small animals, including those which are quite invisible to the unaided eye, are to be removed in a drop of water by means of a dipping tube in the same way, and then transferred to the middle of a glass slip. A cover glass of convenient size is then placed gently on the top of it. First one side is made to rest on the slip, and then the opposite edge, held by a pair of forceps or supported on the point of a knife, is gradually lowered on to the water so as to avoid air bubbles.

In many cases a drop of moderately clear water is full of life, but all the animals are so very small that they move with perfect freedom in the thin film of water between the two glasses, which appear to be in absolute contact. But no pressure must be applied to the cover glass, or the little animals, which generally resemble a small mass of almost transparent jelly, will be crushed and destroyed.

Sometimes, however, objects of a somewhat larger size are to be examined, and it is often necessary at such times to relieve them from the pressure, small though it is, of the cover glass. This is easily done by supporting the glass on two or three little fragments of weed, or by using a shallow cell.

Whether a cell is used or not it is always advisable to cover the objects under observation. This prevents the loss of water by evaporation, and so allows a considerable time during which the development and progress of the specimens may be watched at intervals.

The fronds of duckweeds and the leaves of various aquatic plants often well repay the time spent in examination. Freshwater polypes and fixed infusorians may often be found attached to them. In dealing with these a shallow cell should be used, one just deep enough to contain the piece of weed without pressure.

I will now make a few observations concerning the general management of the microscope, assuming that the reader is provided with an inexpensive compound instrument like that we have figured, and that as yet he is totally ignorant of the manner in which it should be used.

In the first place it is necessary to arrange for the illumination. If it is day, all you have to do is to take a seat where you are facing a window, and arrange your microscope and appliances before you. But by night some kind of artificial light must be used.

For some purposes an ordinary gaslight at a little distance from the operator is good enough; but gaslights flicker considerably as a rule, and, at a distance, they become not only feeble illuminants, but the light thrown on the slip by the reflector below does not always cover the field of observation when low powers are used.

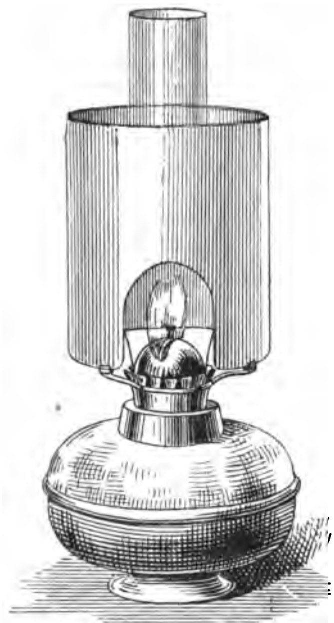


FIG. 41.—LAMP WITH SHADE

Therefore a portable lamp is strongly to be recommended. Microscopists' lamps are to be obtained at all opticians, but any small and cheap petroleum lamp may easily be converted into a really good substitute. Procure a cylindrical tin box large enough to cover the glass of the lamp you intend to use. Knock out its bottom, thus obtaining a tin cylinder open at both ends. Cut out from this a piece of horseshoe shape as shown in the illustration, and then support the shade on three wires fastened to the brasswork just below the level of the flame.

The advantage of such a shade is obvious. It allows the direct rays to fall on the reflector of the microscope, at the same time shutting off the extraneous light that might otherwise dazzle the eyes of the observer and render the image indistinct. The back inner surface of the shade also acts as a reflector, and directs additional rays towards the instrument.

Having put the microscope in a convenient position with regard to the illuminant to be used, move the reflector beneath the stage till the light is directed centrally through the aperture of the diaphragm above it.

The remainder of the preparations depend on the nature of the object to be examined. Let us suppose that it is required to examine a drop of stagnant water, with the purpose, first of all, of finding out what forms of life are present, and afterwards of looking more minutely into the movements and structures of particular species.

A drop of the water is first placed on the middle of a clean glass slip by means of the dipping tube in the manner already described. This must then be spread out into a uniformly thin sheet of water by means of a thin cover glass, which will further serve to prevent loss by evaporation.

The best way to apply the cover glass is as follows: Take up the cover glass by means of a pair of forceps, and apply it obliquely to the slip till it is over the drop, with its lower edge resting on the slip; then lower it gently on the water. A small strip of blotting-paper should then be wiped carefully round the circumference to absorb any water that may extend beyond the cover glass.

The examination should always be commenced with a low power—a two-inch or an inch objective being used; for although this may not enable you to make out the details of the smallest of the living beings, it gives a wider field of view, and therefore better enables you to get a general idea of the contents of the liquid. It will also allow you to follow the movements of those active little creatures which could not be kept within the limited field of a high power.

Focussing, with a low power, is a matter of no difficulty at all; but it is always advisable to start by racking or sliding down the tube till the objective is *too near* to the object before the observation commences, and then raising it as you look through the instrument till the correct distance is obtained. Thus, supposing you are using a one-inch objective, bring the objective to about *half an inch* of the object, and then raise the tube till you get the correct focal distance.

If this precaution is not borne in mind, there is always a danger of racking the objective down on to the stage, thus crushing the object to be examined and breaking the cover glass, for it is impossible to judge of the distance between objective and object as you look down the tube of the microscope.

Most compound microscopes are provided with two racks for sliding the tube; one, called the coarse adjustment, by which the tube can be quickly changed in position; and the other—the fine adjustment, worked by a screw of a very fine thread, by which very slight movements of the tube may be produced with ease.

It is now desired, we will suppose, to view a certain object with a higher power, either in order that its movements may be watched, or to become acquainted with the details of its structure.

First move the slip till the selected object is exactly in the centre of the field, and then change the objective (and the eyepiece too, if required), as quickly as possible if the creature is moving freely about.

It is now necessary to bring the objective very near the object, and in this case much greater care is required than with the low power. Rack the tube down till the object glass almost touches the cover glass, and then, while looking down through the instrument, rack it up very slowly, till the required details are revealed by a sharp image.

Considerable difficulty will often be experienced when observing very active aquatic creatures under a high power, as they are continually darting out of the field. If the movements of such are to be studied, they must have a more limited space than that provided by placing an ordinary cover glass on the slip. A very small quantity of water should be used for examination—only a small fraction of a drop, deposited from a pointed dipping tube, and that should be covered by a cover glass of the smallest size. A *very gentle* pressure may also be applied to the cover glass with a view to the reduction of the thickness of the film of water beneath it, thus limiting the movements of the creatures under examination.

The use of the spot lens has already been described. It may be called into requisition in all instances where the object is colourless and so extremely transparent that its structures are hardly distinguishable with an illuminated background.

In dealing with larger objects, such as the larvæ of aquatic insects and the earlier stages of frogs, toads, and newts, a cell of some kind must be used, the diameter and depth being adapted to the dimensions of the objects themselves. The majority of these aquatic creatures will live for a considerable time in a small quantity of water under a glass cover, and thus give us very favourable opportunities of watching all movements in connection with respiration, digestion, and circulation, as well as those of locomotion.

Thus, many are so transparent that the processes of digestion may be observed within the digestive tube. Contractile blood-vessels, serving the purpose of hearts, may also be seen at work, propelling the vital fluid through the smaller tubes. And, in the case of tadpoles, the blood-corpuscles may be distinctly seen edging their way through the narrow capillaries of the tail-fringe, while a strong current of blood may also be observed rushing through the main vessels in the middle of the tail.

To get a general idea of the character of such movements as these a low power should be used, for with such the illumination is better, the field larger, and the main structures more clearly defined; and the higher powers be used, as already directed, merely for the observation of details within a very restricted area.

A pond-hunter seldom finds it necessary to examine opaque objects, but as occasions for such observations do sometimes occur, we shall conclude this chapter with a word or two on this subject.

The opaque object is placed on a dead black background, such as may be provided by a strip of unglazed black paper. It is well to have suitable backgrounds always ready at hand, and these can be made by pasting strips of suitable paper on one or two of the ordinary glass slips or pieces of stout card of the same size. A few shallow cells, covered at the bottom with the same kind of paper, are also convenient for hard and dry objects that might otherwise easily roll off the slip.

The condenser must now be placed in a direct line between the light and the object, the former being elevated so that it can shine obliquely downward on the top of the latter; and the condenser being placed so that a ray from the centre of the light to the object traverses the centre of the condenser and strikes it at right angles. The distance at which the condenser must be placed in order to concentrate the most powerful light on the object can then be easily found by moving it gradually to or from the stage, keeping it still at right angles to the central ray.

CHAPTER IV

THE POND-HUNTER'S MUSEUM—PRESERVATION OF NATURAL OBJECTS

SOONER or later the student of any branch of natural history experiences a growing desire to gather round him a permanent collection of the objects of his study, not that he prefers the shrivelled and sodden specimens of a museum to the living and moving creatures of the field, nor with a view to the decoration of the apartment in which he spends the greater part of his time, but to enable him to observe and study the structure of those animals which could not have been conveniently examined while alive.

But it is not only for this purpose that such collections are made, for the various specimens form a valuable work of reference, to which the owner can at any time have recourse for a more mature study of things collected years before—things which, when first acquired, were imperfectly known, and of which the relationships and position in the animal kingdom were not understood; but which have since become more familiar, so that their correct positions in the scale of life need no longer be matters of doubt.

Thus the owner of a museum—even of a modest one such as any beginner could establish—is always surrounded by things which recall happy memories of pleasant outings; by well-known objects as well as by things which he has a desire to know better; by a number of forms, of which the study of the structure and relationships is too interesting to be neglected.

The collection, also, is not a source of joy and profit to the owner only, for where will you find a true naturalist who has not a desire to stir up an interest in his pet study in the minds of his friends and others, and what better means to this end could he possibly have than a collection of natural objects, well preserved and arranged, by which he can at any time illustrate his remarks on the beings that have been such a source of pleasure and profit to himself?

In dealing with this branch of the pond-hunter's work we shall first consider the different methods by which the various forms of life are to be preserved, and then append a few remarks concerning the arrangement and labelling of specimens.

Microscopic Life

Many of the very small and delicate soft-bodied creatures of our ponds cannot be satisfactorily preserved by any method, and consequently they must always be studied while living or in a fresh condition. Such of course do not find a place in any permanent collection. They should, however, always be represented wherever an attempt is made to display the creatures of the division to which they belong.

The pencil and sketch-book are to be looked upon as valuable aids to both microscopic and naked-eye observations, and drawings should always be made of at least those creatures which cannot be easily preserved. Such drawings, together with labels containing the information acquired during the examination, may then represent the creatures from which they were taken.

Some really small objects, such as water fleas and cyclopes, can be preserved in fluid, though of course they must always be studied with the aid of a magnifier; but the only satisfactory method of preserving many of the larger delicate objects and the majority of the smaller ones, is to mount them as permanent microscopic objects.

This work, however, cannot be taken up here. The different methods of mounting objects for the microscope form a subject so extensive that those readers who desire to master it are advised to procure one of the manuals devoted entirely to it.

Preservation in Alcohol

We will now consider those animals which can be satisfactorily preserved only in a liquid. These include the soft-bodied larvæ and the pupæ of many aquatic insects, worms and leeches, water spiders, small crustaceans, all the stages of frogs, toads, and newts, small fishes, and the eggs of various creatures.

Alcohol is by far the best liquid preservative for general use, though turpentine and a few other liquids may be used with advantage in certain special cases.

Alcohol is sold in several different qualities. Pure alcohol, quite free from water, is known in the trade as 'absolute alcohol.' There is a heavy duty on it, and consequently it is rather expensive, the usual price being three shillings and sixpence a pound. But it need never be used pure; in fact, we shall see presently that it must of necessity be considerably diluted with water in most instances.

Methylated alcohol, more commonly known as methylated spirit, contains a certain amount of water, and is further adulterated by the addition of wood spirit and mineral naphtha. The object of this adulteration is to make it so unpalatable that it cannot be used for making up intoxicating beverages, while, at the same time, its use as a solvent of gums in the manufacture of varnishes and polishes is not in any way interfered with. Being thus adapted for the purposes of the trades and manufactures only, it is sold free from duty, and costs only about four shillings a gallon. It is, however, much too strong for general use as a preservative of soft-bodied animals, and possesses the disadvantage that it cannot be diluted without the formation of a white precipitate which renders it turbid and almost opaque.

The older methylated spirit, which is free from the mineral ingredient, does not produce this precipitate when diluted, but there is generally considerable difficulty in procuring it now free from duty. It is known in the excise as 'ordinary' or 'non-mineralised' spirit.

If the last-named cannot be obtained, it will be necessary to get the unadulterated alcohol, and dilute it as required for use according to the nature of the objects to be preserved.

One of the most striking properties of alcohol is its powerful affinity for water; and, as a result of this, the water contained in soft animal structures immersed in it is extracted to such an extent that they are shrivelled up till they are often quite beyond recognition. Hence the necessity of well diluting the spirit, and thus satisfying this affinity for water, before any soft structures are placed in it.

It must be remembered, too, that the diluted alcohol is quite as good as a preservative. A fifty per cent. solution is strong enough for any purpose, and even when brought down to twenty per cent. it will prevent decomposition indefinitely, providing it is kept in well-stoppered vessels.

If aquarium accommodation is very limited the collector cannot do better than to take a bottle of diluted alcohol when out on a pond-hunting expedition. Any soft-bodied animals captured may then be dropped into the preservative and killed at once if there is no possibility of keeping them alive, and the bottle stocked in this way will always afford abundant material for work during leisure hours at home. At convenient intervals, too, the contents of the stock bottle may be transferred to smaller tubes or bottles, properly labelled, and made to occupy their respective places in the permanent collection.

Among the interesting and instructive objects that may be preserved in alcohol, we may particularly mention series of specimens illustrating the metamorphoses of aquatic insects and the batrachians. Thus, if some frog's eggs be procured in the spring, there will be no difficulty whatever in bottling a complete series of specimens showing all the changes which the animal undergoes, including several stages in the history of the egg itself.

The one thing to be remembered in connection with spirit as a preservative is this: if the specimen becomes shrivelled the solution of alcohol is too strong. There is no cure by which the distorted objects may be restored to their proper shape; but, knowing the cause of the failure, prevention, which is better than cure, will be easy in future attempts.

Turpentine is often recommended as a preservative for spiders and other creatures. This of course will not be diluted, as it has not any affinity for water as alcohol has, nor does it dissolve in water.

The only advantage of turpentine over alcohol seems to be that in certain cases the natural colours of the objects are better retained.

After an animal of moderate size, such as a frog, small fish, or large larva, has been in spirit for a time the spirit becomes discoloured, and a deposit of extracted matter is often formed on the bottom of the vessel. In this case the liquid with its sediment should be poured off, and replaced by a fresh portion of spirit.

The discoloured spirit need not be wasted. If poured into a large stock bottle it may be used over and over again as a preliminary bath for similar specimens, which will in turn be transferred to a fresh preservative after they have apparently ceased to colour the liquid and produce a sediment. The 'stock' spirit may be decanted carefully so as to leave all sediment behind, or it may be filtered as occasion requires.

When specimens are preserved in a dry state, it is usual to set them in some natural attitude before drying, or to arrange their appendages in such a manner as to display as much as possible of the structure. This may also be carried out in the case of specimens preserved in fluid.

If the latter are simply dropped into a bottle of spirit, not only do they generally lie in a position in which they are not easily observable, but the appendages often become unnaturally doubled or contorted. The spirit, too, is a hardening as well as a preservative fluid, and therefore it is not generally an easy matter to 'set' specimens that have been immersed in it for some time.

Very small objects may generally be well displayed in tubes or bottles by simply suspending them from the cork or stopper by

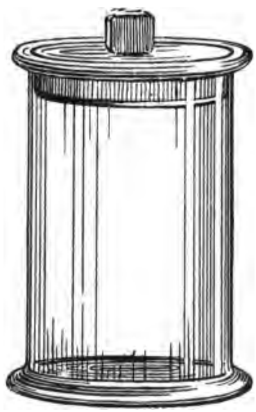


Fig. 42.—A wide Specimen Jar

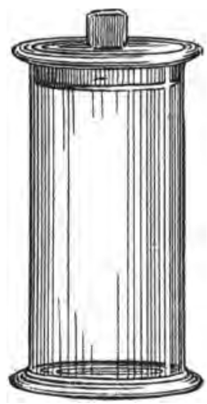


Fig. 43.—A narrow Specimen Jar

means of a fine silk thread; but larger objects, the parts of which it is required to arrange in some definite manner, may be mounted as follows:

Cut a sheet of thin and clear mica as large as the specimen jar will hold. Place the specimen or specimens on this, lay out the parts as desired, and then hold them in position by means of little loops of silk, brought through the mica with a fine needle, and tied behind. When placed in spirit, a specimen so mounted may be made to occupy the middle of the jar with, to all appearance, no support whatever; for the mica becomes invisible in the spirit, and threads of fine silk are hardly discernible.

Before closing our remarks about the wet method of preserving animal specimens we will give a few hints concerning specimen jars and tubes. The stoppered jars made especially for museum specimens, and commonly known as anatomical jars, are rather expensive, and even a small collection could not be put up in such jars without a very considerable outlay. These jars, however, are not at all necessary, for a very useful and even sightly collection may be formed by the aid of the common wide-mouthed bottles, fitted with good sound corks, providing there is uniformity of pattern. The most useful sizes for a pond-hunter's museum are ¼ oz., ½ oz., 1 oz., 2 oz., and 4 oz., and the smallest of these will be in the greatest demand. The prices of the bottles range from about sevenpence to a shilling a dozen.

Specimen tubes, about two inches long and half an inch in diameter, form the best accommodation for the smallest objects. These may also be fitted with good corks, and arranged in boxes or cabinet drawers in a manner to be presently described.

Preservation of Insects

We must next see what can be done with creatures of a drier nature and harder texture, such as the dragon flies, stone flies, caddis flies, and the beetles, flies, and moths that spend their earlier stages in the water.

We have already recommended that these be captured with a net if on the wing or if of a very active disposition, and taken in glass-bottomed pill boxes if at rest and less wary. Those caught in the net are transferred to pill boxes, and thus all are taken home alive.

The sooner these are attended to the better, for if allowed to remain in their closely confined quarters for any great length of time, it is probable that many of them will have damaged themselves in their struggles to escape.

They must first be killed—of course I am now speaking of those insects which are not to be kept alive for observation or for breeding—and then they have to be set out to dry for the museum collection.

There are several points to be considered even when deciding as to how the insects are to be killed. In the first instance the method employed should be as speedy as possible, not only on the score of mercy, but also because a prolonged fluttering is sure to cause more or less damage to the appearance of the creatures which are to be preserved.

Then, again, the insecticide used should always leave the joints of the dead insects in a supple condition, so that the appendages can afterwards be put into any desired position without any danger of snapping them off. Lastly, no agent should be employed that is liable to permanently change the natural colours of the specimens.

One of the most convenient pieces of killing apparatus for general use is the 'cyanide bottle'—a bottle containing a very poisonous substance called potassium cyanide, mixed or held in position by means of plaster of Paris. Such a bottle may be purchased for a shilling; and, if fitted with a good sound cork, will retain its power for a long time.

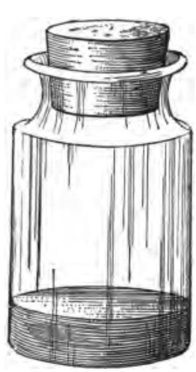


FIG. 44.—THE CYANIDE BOTTLE

As with most other pieces of the naturalist's apparatus, the cyanide bottle is much cheaper when made at home, and the only difficulty in the way of making one's own is the occasional hesitancy on the part of the chemist to supply the cyanide to unknown and, more especially, to young customers. But it is well that such deadly poisons as this cannot be obtained without some little proof of the purchaser's harmlessness, at least to his fellow-creatures. There is another and still greater advantage in knowing how to make the cyanide bottle, for, with a small stock of cyanide always ready in case of an emergency, a new killing apparatus can be made in two or three minutes to replace one broken, and perhaps at a time when an hour or two at least would be spent in journeying to the nearest naturalist's stores, or a day or two would pass before one could be obtained through the post.

The *modus operandi*, then, is as follows: Procure a clear glass bottle, large enough to contain the largest insect you are likely to catch; and, at the same time, of such a size as to be conveniently carried in the pocket or satchel. Put a few small pieces of the cyanide in the bottle—about a quarter of an ounce in all. Now pour about a tablespoonful of water into a small basin or cup, and sprinkle plaster of Paris into it, stirring it all the time, till the mixture begins to set. Then put the plaster on the top of the cyanide, and press it down even with the flat end of a round ruler. Further, do not consider your work complete till basin, stirrer, and ruler have all been well cleared of every trace of the poison.

There is another good way of making a cyanide bottle.

Instead of putting the solid cyanide into the bottle, dissolve it in water, using as little of the latter as possible, and then mix the solution with the plaster, and press it down flat, as before mentioned.

The cyanide bottle is generally an instantaneous killer, but it has one disadvantage, for it renders the joints of insects so brittle that they cannot be set immediately after. If kept in the bottle they gradually relax after a day or two, but then this is not always convenient, especially in the case of an active collector, whose bottle is in almost constant demand. We shall shortly refer to another method by which insects may be relaxed, but it would certainly be far better to employ some means by which they may be killed without causing a rigidity such as the cyanide produces.

Such a means is available in the form of the old-fashioned laurel box, in which the insects are speedily killed by the vapours arising from bruised laurel leaves.

A good laurel box may be easily made by procuring two cylindrical tins of exactly the same size, knocking out the bottom of one, and putting in its place the lid of the other. The box, with a lid at each end, is then provided with a perforated partition of wood or metal, firmly kept in its place by means of a few small brads or a little solder. One compartment is then packed with well-pounded laurel leaves, while the other is reserved for the reception of the insects.

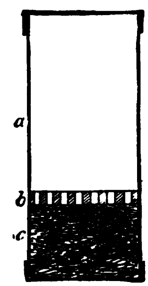


FIG. 45.—THE LAUREL BOX

a, space for insects; *b*, perforated partition; *c*, bruised laurel leaves

The creatures killed by this apparatus always remain so supple that they may be set at the collector's convenience; and, by the way, the same box may be used as a relaxer for those insects which have become rigid through the effects of cyanide, or which have been allowed to become dry and brittle.

The laurel box has, however, one disadvantage as compared with the cyanide bottle; for, while the former requires frequent renewals of fresh leaves, the latter will retain its power throughout a whole season or even longer if properly managed.

One other method of killing insects must be mentioned —one that is now employed by a number of entomologists, and declared by many to be the best. Make a few perforations in the lids of all your pill boxes, and take home all your captives alive in these. Then, on arriving home, put all the boxes into a large tin box with some blotting-paper that has been moistened with the strongest solution of ammonia, and cover the tin to allow the powerful gas to do its work.

The ammonia is not so speedy in its action as either cyanide or laurel, but it leaves the insects perfectly supple; and though it permanently affects the colours of many of the specimens, the natural tints are often restored, as the gas diffuses after they are withdrawn.

Setting Insects

Let us now see how the insects are to be set. In a few instances, as with some of the aquatic beetles and bugs, where the wings are not developed, or where it is not required to extend the wings, the setting is exceedingly simple. The only apparatus required is a few sheets of cork and a supply of pins.

The cork may be obtained in sheets of various sizes and thicknesses from any cork-cutter, or from dealers in naturalist's appliances. The size in the present instance is immaterial, and the thickness should be about an eighth of an inch.

The pins are to serve two purposes—some to run through the bodies of the insects and fix them permanently, and the others merely to keep the appendages in the desired position while the drying is in progress. For the latter purpose ordinary draper's pins will suffice, but only the slender pins made expressly for entomological purposes should be used for the former.

Entomological pins are made in a variety of sizes, but the beginner cannot do better than procure a box of 'mixed pins' from the dealer. He will do well also to keep a sample card of the various sizes and their numbers, so that he may be able to order through the post or otherwise a small quantity of any special kind required, for it is very unlikely that the 'mixed pins' will contain just what he wants in the proportion in which they are required.

Although the sheet of cork mentioned above will serve every purpose as a setting board for certain insects, it will be greatly improved for permanent use if it is glued to a thin slab of wood of exactly the same size, and then covered on the other side with clean white paper, laid on with thin paste. The wood gives firmness and rigidity to what would otherwise be a rather fragile and too flexible support for the pinned specimens, and the white paper covering the top will greatly assist the setting by providing a white background on which the insects, mostly dark in colour, may be very distinctly seen.

In the case of those insects which are to be set with extended wings, different kinds of setting boards will be required. These may be purchased ready made, but such are generally adapted only for butterflies and moths and a few other orders of insects, and would certainly not fulfil all the requirements of one who makes aquatic life a special study.

The ordinary setting board consists of a wooden base, covered with a grooved piece of cork, the groove being made to accommodate the body of the insect while its wings are spread on the surface on each side.

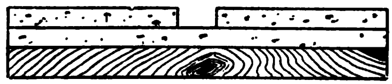


FIG. 46.—SECTION OF A SETTING BOARD

The easiest way to make such a board is to cut a piece of wood about a foot long, one quarter of an inch thick, and of such a width as to slightly exceed the length (measured from tip to tip of the extended wings) of the largest insect for which it is to be used. This wood is then covered with a sheet of cork of the same size, which is glued on; and then on the top of this is laid two other strips of cork, each a little less than half the width of the former, leaving a space between them down the middle of the board. As soon as all have been glued together, the board is put aside to dry under pressure. Lastly, when quite dry, the edges are trimmed, the surface is smoothed, and the top covered with thin white paper which is laid on with very thin paste.

Another way is to glue a *thick* sheet of cork to a base of wood, cut a groove in the cork, and then finish off as before; but this plan is not nearly so easy unless one is provided with suitable tools for cutting the groove.

The accompanying figures of sections of setting boards show three forms in common use—one with perfectly flat sides, one with flat but sloping sides, and a third with rounded sides.

The selection of one or the other of these is generally only a matter of taste, but the pond-hunter will generally find the first answer his purpose as well as any.

We have already alluded to these setting boards as being adapted more particularly for the setting of butterflies and moths, of which none of the former and only a few of the latter come within the province of him whose work is confined to ponds and streams; but with a few slight modifications, such as would readily suggest themselves to any interested worker, they may be rendered extremely useful for the setting of numerous aquatic insects.

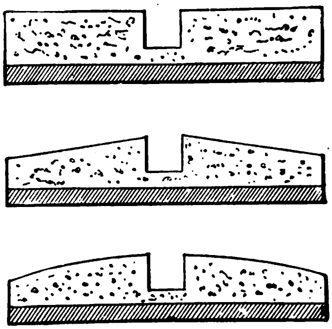


FIG. 47.—SECTIONS OF THREE SETTING BOARDS

Without any alteration at all, setting boards of the above pattern will answer well for many of the aquatic flies, such as the May Flies (*Ephemeridæ*), Stone Flies (*Perlidæ*), Alder Flies (*Sialidæ*), and Dragon Flies (*Odonata*), as well as for the few aquatic lepidoptera; but it will often be found convenient to have the groove very much wider in those instances in which it is desired to set out the legs as well as the wings, the groove in these cases having to accommodate the extended legs as well as the body.

In setting the *Lepidoptera* (Butterflies and Moths) it is usual to keep the legs folded under the body, or to bring the front pair forward while the remaining four are folded, and for this purpose the groove need be but little wider than the bodies of the insects. A pin of suitable size is passed vertically through the middle of the thorax, and then into the cork at the bottom of the groove; and the extended wings are held in position by means of little paper straps which are pinned to the board as shown in fig. 48.

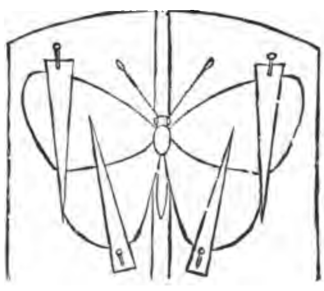


FIG. 48.—A BUTTERFLY ON THE SETTING BOARD

The next illustration (fig. 49) shows a simple method of setting a dragon fly. Here the wings are held in position in exactly the same manner; and at the same time the legs are extended in the wide groove of the board, and secured where necessary by means of pins driven into the cork either in front or behind, according to the direction in which the legs have a tendency to spring.

After these few remarks and suggestions, the reader will probably

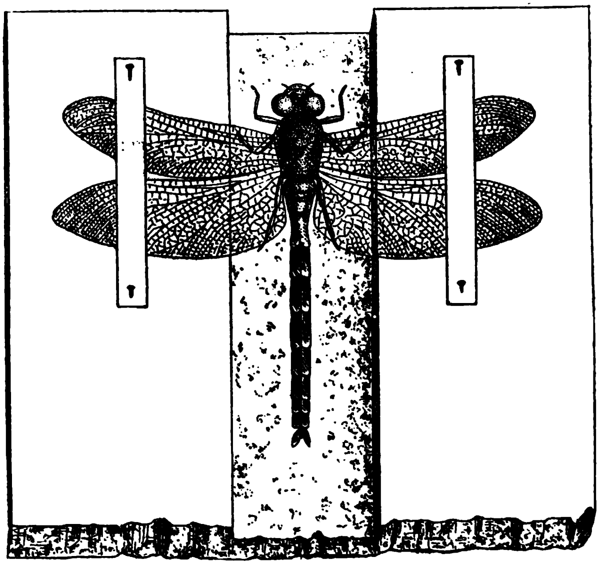


Fig. 49.—A Dragon Fly on the Setting Board

have no difficulty in designing a setting board to answer any of his requirements, there being little to consider besides the width and depth of the groove.

Relaxing

It will be necessary to state here that those insects that are to be preserved dry should, as a rule, be placed on the setting boards as soon as possible after the return from the field, while their limbs are still soft and supple.

We have already recommended that the winged creatures be captured by the net or taken in pill boxes, carried home alive, and then killed by means of the cyanide bottle, the laurel box, or ammonia. But it is not always convenient to set them all right away and if put aside they soon become so dry and rigid that setting then becomes an impossibility.

We have further pointed out that potassium cyanide renders them very stiff, though a few days' confinement in the cyanide bottle often brings them back to a workable condition; also that the laurel box may be made to serve the purpose of a relaxer. But when a number of pinned insects have been allowed to become dry, a more commodious relaxing apparatus is often very useful to soften the joints of their various appendages—legs, wings, antennæ, &c.

Such a relaxer is easily extemporised as follows: Select a basin or dish large enough to contain all the dry specimens. Pour a little water into it, pin all the specimens to pieces of cork, and float the cork on the water. Then cover the vessel with a sheet of glass. In a day or two the smaller insects will have become so supple that setting may be commenced, but the larger ones must be allowed a longer period to undergo the necessary softening.

As the relaxing of the latter progresses there is always a danger of the development of mildew unless some means has been taken for the prevention of such vegetable growth; and though this may not always be absolutely necessary, yet it is advisable to adopt it at all times. A drop or two of crude carbolic acid in the water of the relaxer is quite sufficient to check any development of mildew.

Our remarks concerning the killing and relaxing of insects apply to nearly every case likely to come within the pond-hunter's experience, but there are still a few points concerning the setting of certain kinds which require or admit of some special treatment.

Some of the short-winged insects, the larger diptera for instance, do not require grooved setting boards. They should be pinned through the thorax, and fixed on a flat board as recommended for the wingless species. The legs are first placed, and fixed if necessary, in natural positions, and the wings may then be kept extended by means of small strips of thick paper or thin card mounted on pins.

Beetles

Beetles have two pairs of wings, the outer pair (*elytra*) being hard and horny, and serving merely as a protection for the longer membranous wings which are folded beneath them when not in use.

When beetles are to be set with their wings closed, it is usual to pass the pin through one of the elytra, a short distance from its base, and not through the thorax as with other insects. This of course does not look so well as if the pin were central, but it need be but little out of the middle line; and, for the sake of uniformity, all should be pinned on the same side. Then as to which side shall be chosen, this is a matter of no importance if your collection is to consist entirely of your own specimens, that is, of specimens which you have taken yourself. But naturalists generally greatly assist one another in extending their collections by exchanging their duplicates for those of their friends; and for this reason you will see at once the advisability of a recognised uniformity in the methods of setting and preserving, in order that the cabinets of collectors may not exhibit a disagreeable variety of tastes and fancies.

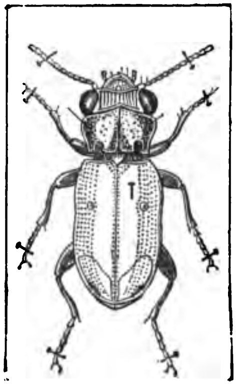


FIG. 50. — A BEETLE PINNED AND SET WITH WINGS CLOSED

Hence it will be well to observe, in the case of beetles, that it is usual to thrust the pin through the *right* elytron, as shown in our illustration.

Many of the aquatic beetles are so small that it is impossible to pin them without injury, even with the finest pins made, and these should be mounted on card by means of gum.

It is particularly necessary in this case that the joints should be so supple that the legs, wings, and antennæ are very easily secured in their respective positions, for the gum has very little holding power while in a fluid condition.

A thin card of the finest quality should be used for this class of work, good 'ivory' visiting cards being perhaps as suitable as any for the purpose.

FIG. 51.—A SMALL BEETLE MOUNTED ON CARD, ENLARGED

The best gum to use is tragacanth, which may be obtained in the solid state from any chemist. A small piece of the gum is placed in a little bottle of water and set aside. It soon begins to swell up enormously; and, after a time, the whole mass is converted into a thin jelly, the consistency of which may be altered if necessary to the best working condition by the addition of either more gum or more water.

Test your specimens first to see if they are in a fit condition for mounting; and if they require relaxing put them in the cyanide bottle, laurel box, or any other relaxer for a day or two.

When ready, cover a card with the gum, set the beetle as desired by means of a needle, and then allow it to dry.

Several small beetles may be mounted on the same card, which may afterwards be cut into neat oblong strips, each with a single specimen. These strips are then ready to be pinned for the cabinet.

This method of mounting is not confined to small beetles only, nor even to small insects. It is certainly the best dry method of preserving small insects of all orders; but, in addition to these, there are many large species with legs so long and slender that it is a very difficult matter to keep them intact unless these limbs are flattened down and gummed to a card. But in this matter the setter must use his own discretion.

Before closing our remarks concerning the setting of insects, we have one more case to mention, and that is the preparation of the larger water beetles with wings extended.

For these a setting board with a very wide groove is required. In fact the groove, which, by the way, should be shallow, must also be wide enough to contain the body and the walking legs.

Pin the beetles through the *thorax* now; and, after arranging the legs, separate the two elytra, and fix them in an extended and slightly raised position. Now you will observe the folded membranous wings displayed. Open them out carefully by means of a blunt needle, and then hold them in position on the setting board just in the same way as you would the wings of butterflies and moths.

Preserving Crustaceans

We may now say a word or two concerning the preservation of freshwater crustaceans.

The smallest of these—freshwater fleas and cyclops—may well be included under the head of microscopic life. They may be preserved in dilute spirit, and stored away in small specimen tubes for future study; or they may be mounted on glass slips as permanent microscopic objects.

Freshwater shrimps also may be well preserved in spirit. Their natural colour will be more or less destroyed by this method, but their form will remain perfect. If allowed to dry, their bodies shrivel up and assume a very unnatural appearance.

Crayfishes may be preserved either wet or dry. In spirit they lose their natural tints, but in all other respects remain perfect. The wet method of preserving animals possesses the advantage that they may be dissected and examined at any future time, and parts selected for detailed study with the aid of the microscope or for the preparation of permanent microscopic slides. But when weight and space are considerations, the necessary array of specimen jars and tubes charged with a large quantity of alcohol is a great drawback to the collector, who therefore adopts the dry method wherever practicable, more particularly with the largest specimens.

Crayfishes may be very satisfactorily preserved in a dry state as follows: It will be observed that the body consists of a number of segments moveable one on the other, the first one (really several segments fused together), called the cephalo-thorax because it consists of both head and thorax combined, being much larger than the smaller ones which form the abdomen.

Sever the body in two by cutting through the soft structures between the cephalo-thorax and the abdomen, and then remove the internal organs and flesh by means of a hooked wire, assisted by the occasional use of a small brush.

In the case of small specimens this is quite sufficient, but larger ones should have their front claws removed and cleared in a similar manner.

Now set out the parts on a board to dry, having placed all the appendages in the position they are finally to assume. The drying may be conducted most advantageously in the open air, not only because this is the quickest plan, but also because, however carefully the clearing of the soft parts may have been accomplished, there is sure to be enough remaining to give a questionable taint to the atmosphere of an ordinary apartment.

A few days' access to the free air in dry weather is quite sufficient to complete the drying of the parts, which may then be fastened together by means of a little coaguline.

At least two crayfishes should be preserved for future reference and study, one being placed in the collection so as to show the upper, and the other the lower surface.

Freshwater Shells

We have one other class of animals to deal with in this chapter, viz. the mollusca.

The aquatic species of this class are all protected by shells, and it is common for beginners in this branch of natural history to confine themselves to the collection and study of the shells only, neglecting altogether the peculiarities of the soft-bodied animals which they enclose.

This, however, is easily explained. The shells are always interesting and frequently very pretty objects; and are, moreover, easily preserved. But it will be admitted without hesitation that the shells are, after all, only the homes of the creatures concerned —that they are merely the lifeless calcareous secretions of the 'mantles' of the animals which they protect; and that, although it is possible to identify every species of the aquatic molluscs by a careful observation of the shells alone, yet he who confines his attention to these knows but little of their natural history.

What, then, should the pond and stream hunter do, and, equally important, what should he *not* do?

To take up the latter question first, let me impress upon him that he should never be in a hurry to kill the animals in order to obtain the clean shells. A few of every species taken should be placed in the aquarium for the observation of their habits. And then, having selected what is required for this purpose, always set aside a few for preservation in fluid, in order that the animal itself may always be at hand for reference and examination when fresh specimens are not to be obtained.

In cases where shells only are required, it is usual to kill the molluscs by immersion in boiling water, and this is undoubtedly the most merciful way of dealing with them. But this causes the animals to so contract and shrink within their shells that they are practically worthless for the examination of some of the softer structures.

Perhaps the best way to proceed with those which are to be preserved entire is this: Place the living molluscs in water, and let them remain till their bodies are as fully extended as during their most active moments—till the headed members are crawling with their tentacles fully protruding, and the bivalves have their 'feet' and 'siphons' extending from their gaping shells.

Now add a solution of corrosive sublimate to the water. This must be done very gradually, and the animals will soon succumb to the effects of the poison, dying with some of the softer parts still visible and well extended. When dead, they may be placed in weak alcohol, not stronger than about twenty per cent. Here they must remain till colouring matter ceases to be extracted from their structures, and then they should be taken out, lightly brushed all over with a soft camel-hair brush, and finally housed in labelled bottles with stronger spirit, which, however, should not be strong enough to cause them to shrink.

In this manner it is possible to obtain a collection of molluscs that reveal characteristics which are aids to identification and classification, and which are important supplements to those features that are revealed by the empty shells alone. Such specimens, too, if properly preserved, are always available for dissection, though for this purpose they are not so good as freshly killed molluscs.

We must now turn our attention to the preservation of the shells, dealing first with the univalves or one-shelled molluscs, more commonly spoken of collectively as the snails.

After these have been killed by immersion in boiling water as already directed, the animals are extracted by means of a pin with a bent point, of course using a very fine pin for the small species.

The extraction should be performed with care, pains being taken to remove the animal entire, or a portion will remain within the small whorls of spiral shells, quite beyond the reach of the extractor.

This, however, is often unavoidable; and in such cases, as well as with some very small shells from which it is almost impossible to remove the animals with a pin, the only way to clear out the soft matter is to allow it to decompose in water, which should be frequently changed during the process.

As soon as the shells are cleared they should be brushed lightly, and then put in an airy place on a sheet of blotting-paper to dry.

Some of the freshwater snails are provided with a shelly or horny lid (the *operculum*) like that of the marine periwinkles and whelks, by which the shell is closed when the animal retires. This should always be preserved with the shell. It should never be gummed or cemented to the shell itself, but placed in such a manner that it can be easily removed for the examination of its interior surface as well as of the interior of the shell. The 'body whorl' of the shell may be lightly packed with cotton wool, to which the operculum may be fastened by a little gum or coaguline.

The shells of the larger bivalves are to be treated in this way: After the animals have been killed in boiling water, the muscular pillars which hold the valves together must be cut through with a sharp penknife or scalpel, and the body removed. It will now be seen that the two valves are kept open by the elasticity of the strong ligament at the hinge.

Gently press the valves together till they are in close apposition, and then tie them round with cotton or thread, and set aside to dry. They will then remain closed after the binding has been removed.

Some of the smallest of the bivalves are too delicate for contact with the point of a knife. They may be cleared of their contents by simply allowing the animal matter to decompose in water, the water being changed at intervals till they are quite clean. The valves may then be held together during the drying operation by means of little spring clips, the greater portion of the moisture having been previously removed by strips of blotting-paper.

FIG. 52.—SPRING CLIP FOR HOLDING SMALL BIVALVE SHELLS

One specimen of each bivalve shell should always be preserved in such a manner as to allow the structure of the hinge to be examined. This can be easily done by opening the shell wide and placing just sufficient weight on it to keep it open till the ligament is perfectly dry.

Lastly, a word or two concerning the cleaning of the exterior of the shells. In many cases they will be found incrusted with the sediment of ponds, and still more frequently will they be partly or entirely covered with vegetable growth.

This may be removed by means of a brush—a tooth-brush answering admirably for the larger and thicker kinds, but of course a softer brush for the delicate ones.

There will be no need, however, to clean every specimen in this way. A layer of vegetable growth or other deposit gives a natural appearance to the shell; and, as long as one or two of each species are sufficiently cleansed to show the details of form and structure, the others may with advantage be allowed to exhibit those appearances which so commonly characterise the tenanted homes of the pond and stream.

The Collection

It is not long before one who is deeply interested in natural history finds that he has become the owner of a gradually increasing collection of objects that have been put on one side at various times for future examination or because of some unusually pretty appearance.

At first no special difficulty arises, the specimens being deposited without definite arrangement on any spare shelf or in any unoccupied corner. But after a time matters present a more serious aspect. 'Let me see; where shall I put this specimen jar, and what shall I do with this box of insects?' says the young naturalist, whose treasures accumulate in proportion as his love for his subject grows more intense.

He sees that confusion is beginning to prevail, and soon awakens to the melancholy fact that the space at his command is strictly limited. With a puzzled expression he scans his present situation, and thinks over the various alternatives before him.

Shall he cease to add to his accumulating store of treasures? No; that is quite out of the question, for not only must he study the objects collected at his leisure, but they must needs be always at hand for comparison and the determination of their relationships. And the negative reply is still more emphatic when for a moment he entertains the idea of discontinuing his observations.

Something must be done, and that speedily. Some kind of accommodation must be provided in order that the objects may be saved from destruction, and that they may be so arranged as to form a convenient work of reference as his study proceeds.

Other difficulties then arise, and these seem at first almost insurmountable. How nicely things could be managed if his space were infinite and cash without limit!

But the first difficulty can be soon diminished. A few shelves here and a few compartments of some kind there will enable the present store to be set in order, with an allowance for a further increase. But the second consideration still stands out prominently before the collector—How shall he arrange them?

It is quite possible that some of my readers are so fortunately situated that the pecuniary side of the question presents no difficulty at all. Their wants are explained to some obliging dealer, or their rough plans exhibited to a neighbouring cabinet-maker, and the ordinary apartment develops like magic into a luxurious private museum and naturalist's laboratory combined.

Such readers, however, are undoubtedly in the minority, hence it is our duty to provide hints for the assistance of those who require a suitable but inexpensive storehouse for their specimens. Let us see, then, what can be done in this direction.

First, as regards the objects that have to be preserved in fluid, those in jars and bottles simply require shelf accommodation, but should always be protected from dampness and dust wherever possible. A damp atmosphere, though it cannot affect the specimens themselves, causes considerable annoyance by loosening the labels. Dust, too, does no injury to bottled objects, but a cleanly appearance and a great saving of time will be the result if the specimens can be stored in a well-fitting cupboard or cabinet.

All the very small objects that require a fluid preservative should be stored in specimen tubes fitted with good corks. The tubes may then be laid side by side in cardboard glass-topped boxes or in shallow trays or drawers. The labels in this case may be gummed round the top of the tubes, leaving nearly the whole of the length clear for observation of the contents; or each tube may be tied to a strip of card, as shown in fig. 53, and any desired memoranda written thereon instead of on a gummed label.

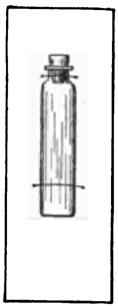


FIG. 53.—A SPECIMEN TUBE MOUNTED ON A CARD

Insects and other creatures preserved in a dry state present greater difficulties, for it is no easy matter to keep them quite out of the reach of certain museum pests which devour portions of their bodies, often causing the remainder to crumble away. Nothing can be considered highly satisfactory for these except the well-made cabinets and store boxes made by experienced hands for the express purpose.

It is not absolutely necessary, however, that glazed and practically airtight compartments be used, provided a liberal supply of some suitable insecticide is introduced and renewed as occasion requires, and that a constant watch is kept for the intrusion of the little destroyers.

Glass-topped cardboard boxes, such as are largely used by drapers for their small goods, are by no means to be despised. Narrow strips of sheet cork glued on the bottoms of these serve to hold the pins firmly; and a good allowance of camphor or naphthaline (albo-carbon) in each will prevent the intrusion of destructive pests.

The only advantage of the glass top is to allow one to see at a glance what each box contains, but it must be remembered that continued exposure to light will very soon cause the natural colours of the specimens to fade. Hence, if of necessity this inexpensive accommodation be chosen for the specimens acquired, the boxes should be shut up in some kind of case so that light as well as dust may be entirely excluded. By securing a dozen or so well-made cardboard boxes, and then making a little cabinet or box in which all can be snugly packed, one can provide a very satisfactory, although extremely cheap, storehouse.

Intermediate between this arrangement and the costly cabinets of the naturalists are the store boxes supplied by dealers. These are wooden boxes, of various sizes, and of such a depth that they will contain a double layer of specimens, for which purpose they are lined with cork both on the top and bottom.

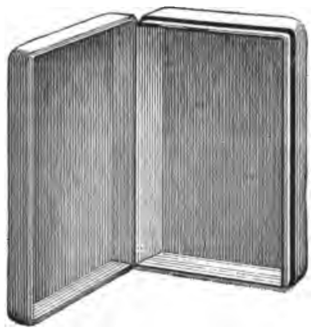


FIG. 54.—A STORE BOX FOR DRY SPECIMENS

The shells of aquatic molluscs should be arranged in cardboard or chip boxes of suitable size. A very inexpensive and neat plan is to make a collection of ordinary matchboxes — the inner sliding portions—re-cover them with good white paper, divide them into compartments by strips of card for the smaller species, and then lay the shells in them on beds of wadding. This will prove very satisfactory for the majority of British freshwater shells, but special boxes will have to be procured for the few large bivalves.

These larger boxes should, for the sake of neatness and economy of space, be in size exactly a multiple of the smaller, so as not to interfere in any way with the uniformity of the rows or columns in which they are placed.

It is certainly advisable to keep the smaller shells in glass-topped boxes. These may be the ordinary glass-topped pill boxes supplied by dealers, or pieces of glass could be obtained from any glazier of exactly the size to cover the square boxes used.

The best arrangement for specimens kept in drawers or boxes, whether dried or preserved in tubes, is that of vertical columns, in which the various species are placed in their proper scientific order. Each column should be headed by the name of the family to which its specimens belong. Immediately below this is placed the name of the first genus of that family, and then follow the specimens or series of specimens belonging to that genus, each species having its specific name *below* it.

The collection should, as far as possible, illustrate the various stages of those creatures which undergo metamorphoses. For instance, in the case of aquatic insects, the larvæ, pupæ, and even the eggs may appear in company with the perfect form, thus rendering the collection of far greater value than it otherwise would be.

As regards the labelling of a private collection of natural objects there is a difference of opinion. It has been said that 'if the specimens are not worth *knowing* they are not worth *having*.' And, it may be added, 'if well known, why label them?' This is all right as far as it goes; but it must be remembered that each one of the specimens is at first new and unknown to the collector or observer; and for this reason alone he might attach a label till the object is familiar both by name and by sight. Further, it may be hoped, there are but few naturalists who would not be pleased to make use of their collections for the benefit of their friends, and to these the names would probably prove very useful indeed.

Again, what are the labels to show—names only? By no means. The naturalist is not only interested in the mere identity of his treasures. He is equally concerned about their habits, habitats, food, dates of capture, and various other matters, all of which should appear in the form of memoranda, either on the label beneath each specimen, or, which amounts to the same thing, in his note book under the respective name.

A good museum has been rightly defined as 'an instructive collection of labels, illustrated by specimens;' and in many cases it is, to my mind, a matter of doubt as to which could best be spared—the specimen or its label. And I should strongly advise young naturalists to label every specimen in their collections, not necessarily with the names where these are well known to them, but with dates, localities, and any interesting observations made either at the time of capture or subsequently.

CHAPTER V

AQUARIA AND THEIR MANAGEMENT

I HAVE already referred to the fact that many household utensils may be converted into successful aquaria such as will serve all the purposes of the naturalist, and that the more expensive 'bell' aquaria and rectangular or polygonal 'tanks' are required only when it is desired to combine the ornamental with the useful. And I see no reason whatever why the lover of aquatic life should not place some of his pets in a beautiful home where their graceful movements and interesting habits may be easily admired, and where their forms and colours may be blended and contrasted with the equally admirable forms and tints displayed by a judicious selection of growing vegetation and a tasteful rockery, just as the botanist who rears plants for his own study and research adds to the charm of his collection by arranging them in such a manner as to make his garden or conservatory an ornament to add to the beauty of his home. All these considerations will be borne in mind in the present chapter, which is to be devoted to hints and suggestions concerning the formation and management of fresh-water aquaria.

In the first place let it be clearly understood that a single aquarium is practically useless to the student of freshwater life unless he is content to give attention to various species alternately, keeping only those in captivity at any one time that live in harmony. To prove this, put all the takings of a pond hunt on a summer's day into an aquarium together, and watch the result. The ensuing scene is one of constant warfare, the stronger and more voracious (not necessarily the larger) species attacking and devouring the more harmless and quiet, till at last the field, strewn with dead and partially devoured victims, is held by the few surviving conquerors, and the water is rendered putrid and perhaps dangerous by the products arising from the decomposing remains of the vanquished. A general turn-out and cleansing of the aquarium will now be an absolute necessity.

Of course the carnivorous creatures must be provided with food, and perhaps it is only fair that they should have their natural diet, but they should be kept in a separate compartment, and be supplied with no more food than they devour.

Those who have no desire to establish an ornamental aquarium, but wish to reserve all their energies for the stern study of freshwater life, need have no other utensils than are daily demanded in the domestic service. Here are some suggestions:

For fishes and the larger molluscs, nothing is better than a large tub placed in a shady corner out of doors. It is really much superior, from a naturalist's point of view, to a glass aquarium of any kind, as it more nearly fulfils the conditions of the natural haunts of the creatures concerned. Like the pond and stream, it leaves a considerable amount of surface exposed to the atmosphere, and admits light from above only. A layer of sand or fine gravel at the bottom supplies a good natural bed on which the 'bottom fish' and the bivalve molluscs can rest and burrow, and in which may be planted a selection of water plants; and a mass of loosely piled irregular stones will give the shelter and semi-darkness which the more seclusive species require.

If an aquarium of this description is to contain creatures that inhabit rapid streams and delight in clear running water, it is simply necessary to place the vessel under a water tap, and bore a hole in the side of the tub, a few inches from the top, for the waste to flow away.

Then again, for the rearing of amphibians through their earlier stages the tub is, *par excellence*, just the thing. For this purpose the water should be only a few inches deep, and well supplied with weeds; and piled stones should reach above the surface as a resting place for those whose strictly aquatic life has terminated.

Crayfishes and freshwater shrimps delight in shallow running water, with a sandy bottom and plenty of hiding places among stones; and nothing serves the purpose better than a shallow tub or stoneware trough with a constant supply and a waste pipe. It will occur to the reader, however, that a strainer of gauze or muslin should cover the exit for waste in order that the small crustaceans may be prevented from escaping.

A large aquarium such as that which we have already recommended for fishes and the larger molluscs might well be used for the larvæ of aquatic insects and other creatures of small and moderate size when a number are required as 'stock,' but those which are to be kept under close observation in order that their habits and metamorphoses may be watched may be transferred for the time being to earthenware vessels or, in the case of very small species, to glass jars; but in all cases a layer of sand or gravel and a supply of growing weed must be provided for purposes of aëration as well as for the sustenance of the vegetarians.

Glass vessels of all kinds have the objection that they admit too much light, and thus they not only cause the inmates to exist under conditions unnatural to them, but also encourage the rapid development of confervoid vegetation which sooner or later covers the glass so densely that observations are impossible, while sometimes the whole of the water is converted into one green mass. This being the case, it is advisable to shut off much of the light by a screen of some kind which can be readily removed at times when the contents are under inspection. Cylinders of paper, more or less opaque, may be made to drop down over the jars loosely. Or, if preferred, a piece of tissue paper may be pasted permanently over the side on which the strongest light falls. The former method is perhaps preferable, for when the moveable screen is lifted from its position the objects within the jar are more easily watched than when backed with a semi-transparent ground.

Whatever be the form or nature of the aquaria used, direct sunlight should be avoided, especially the powerful rays of midday; and to this end a window with a northern aspect should be chosen if possible.

So far we have confined our remarks to nothing but the rudest appliances which, although they supply absolutely all that is necessary for the successful study of freshwater life, constitute nothing of an ornamental character, but rather tend to give an appearance of untidiness and disorder to the naturalist's apartment; but we shall now consider briefly a few forms of aquaria that may be made to please the eye as well as to instruct the mind.

Of these the well-known bell glass is by far the most generally used and most easily procured. Yet how miserable are the attempts to convert it into an object of beauty, and how imperfectly known are the principles on which its successful management depends! We commonly see this vessel containing nothing whatever with the exception of a few neglected fishes. No soil of any kind to form a bed, no hiding place for a cool shelter from the blazing rays to which the creatures are so often exposed, and not a scrap of weed to exercise a purifying influence on the water or to relieve the monotony of the scene.

It is no wonder that so many discontinue aquarium keeping after a very short experience. The amount of attention necessitated through ignorance, and the great trouble and loss of life caused by mismanagement, make the owner give it up in disgust and declare that the aquarium is not nearly worth its cost.

But even the bell-glass aquarium, unnatural as it is, may be made a success in every respect if due regard be paid to the requirements of the creatures contained therein and to the general principles which are involved. But perhaps it will be better just now to confine our remarks only to the selection and construction of the different forms of vessels that may be used, and then deal with the management of aquaria collectively.

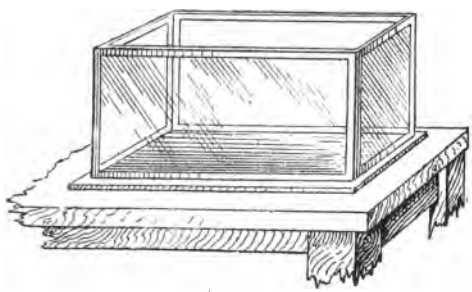


Fig. 55.—The Rectangular Tank

A square or oblong 'tank' may be easily made at a low cost. Only one side need be of glass, the remainder being either of wood, metal, or slate.

If wood be chosen, first decide on the size of the base, which will generally be arranged according to the space at disposal, or the table or other rest on which the aquarium is to stand. This should be of hard wood—mahogany, teak, and oak are all good for the purpose—about one inch or more in thickness, well levelled and smoothed on the upper surface.

The wood for the back and the sides need not be so thick as that which forms the base, half an inch being quite sufficient for indoor tanks with a capacity of only a few gallons. The three pieces chosen should be neatly dovetailed together after having been faced, and the grooves cut to receive the glass. When this is done, place the four sides temporarily in position on the base, and pencil out on the latter the exact sizes and situations of the grooves to receive them. These grooves need not be deep, and when they are ready the back and sides should be held firmly by screws driven through the base from below.

Now follows the important operation of rendering the structure perfectly watertight. A liberal supply of melted pitch should be allowed to run freely round all the joints and in the grooves, and the whole surface of the wood must also be covered in order to stop all the pores. While the pitch in the grooves is still hot and soft, push the glass in its place, and then smooth over the whole of the pitched surface with the flat face of a hot iron. A warm iron wire may also be well worked round the edges of the glass, both inside and outside.

The tank is now ready for water, but it is not advisable to introduce any living things for a day or two, as the water at first may dissolve out harmful impurities from the pitch, and may also partake rather freely of the odour of the pitch itself.

Slate is far preferable to wood for rectangular aquaria, but is more expensive, and much more difficult to work. Nevertheless it is to be strongly recommended to those who do not mind the extra cost and the time required for the cutting and grooving, or to those who can get the slabs ready cut and prepared by an experienced workman. In this case all the parts fit in grooves, and the slabs are held firmly together by metal rods and nuts. It will be far better, too, to use the cement recommended below instead of the pitch.

A very neat tank may also be made by soldering together a framework of 'angle zinc,' and attaching it to a base of sheet zinc supported on a slab of wood. Roofing slates may then be used for the back and sides, and glass, as usual, for the front; or all four sides may be of glass as a matter of convenience, but if so the back and ends should be rendered opaque by means of a coat of paint or a layer of paper on the outside.

In making up a tank of this description care must be taken in the preparation and selection of a good cement, for pitch, though it answers well for wooden aquaria, does not adhere so firmly to metal and slate.

A good stopping may be made by mixing two parts of litharge, two of plaster of Paris, two of very fine sand, and one of finely powdered resin, and then working the mixture up into a putty with boiled linseed oil and a little driers. This should not be made until required, and must be allowed a week or two to harden before water is put into the aquarium.

Whatever be the materials used in the construction of a rectangular tank, it should always be filled with water and allowed to stand for a day or two before it is stocked. This will not only give a good opportunity of thoroughly testing its water-resisting power, but will allow any objectionable soluble matter in the cement or on the surface of the other materials to be dissolved.

This water is then run off, and the final preparations for the reception of the living things may be conducted as follows, bearing in mind that the instructions here given apply to all aquaria, whatever be its form or size or the nature of the proposed inhabitants.

First introduce a layer of clean sand to the depth of a few inches. If the sand be taken from the bed of a neighbouring rapid stream it may not require any washing, but if obtained in a sand-pit or from the sea-shore a thorough cleansing will be absolutely necessary, in the former instance to remove clayey matter and miscellaneous impurities, and in the latter case to dissolve out all traces of salt.

The best method of washing is as follows: Place a clean tub or large pail under a running tap, and the sand to be washed at the left of it. Then take the latter, a handful at a time, and drop it gradually into the running water while you keep the whole in a vigorous motion by stirring it round with a stick held in the right hand. Continue this till the water runs away perfectly clear, and till a drop of it, evaporated to dryness in a perfectly clean watch glass, leaves no more residue than a drop of the clean water direct from the tap. This latter test is necessary because water which is perfectly pure to all appearances may contain soluble matter, possibly of an objectionable nature.

When satisfied as to the cleansing of the sand, put it into the aquarium, and proceed at once to plant the weeds that you have selected. In this matter it will be advisable to introduce a variety of vegetable life rather than to confine yourself to any one species; for by so doing you not only give yourself an opportunity of becoming more intimately acquainted with the various forms of aquatic vegetation, but will also learn, more rapidly than you otherwise would, which species thrive best under the conditions to which you have subjected them.

As already intimated, the aquatic plants serve various purposes

They are not only beautiful ornaments in themselves, capable of producing what may truly be termed an aquatic flower-garden, but they keep up a constant supply of oxygen gas for the respiration of gill-breathing animals, and also represent so much food for the vegetable feeders. And since some of these plants are far more ornamental than others, and some species are also particularly liberal in their evolution of oxygen, and, again, some are special favourites as articles of diet, it will be seen that the selection becomes a matter of considerable importance. This being the case, we shall presently devote a little space to the consideration of some of the most useful and interesting species, dealing with their peculiarities as far as the management and well-being of the aquarium are concerned. But to return to our task.

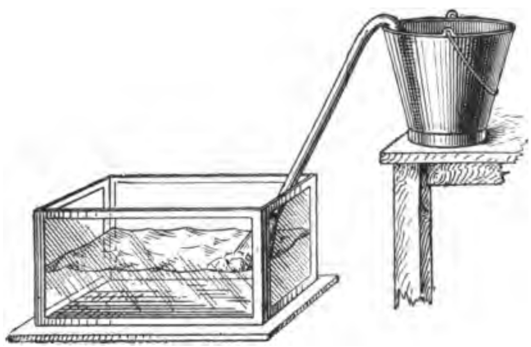


FIG. 56.—FILLING THE AQUARIUM BY MEANS OF A SIPHON

After fixing a liberal supply of aquatic plants by their roots in the bed of sand, scatter a layer of clean pebbles of various sizes, and build up a few little rockeries of rather large and irregular stones, piling them loosely in such a manner as to leave numerous hiding places for those creatures that prefer their hours of seclusion, and then proceed to run in the water.

In this matter be as gentle as possible, so that none of the arrangements may be disturbed. The best way is to mount a large pail of water above the level of the top of the aquarium, and then introduce a bent tube—glass, or new 'compo' gas pipe—the shorter arm of which reaches to the bottom of the pail, and the longer one dips into the aquarium. By withdrawing air from the tube by suction at the end of the longer arm till the water reaches a level in that arm below the surface of the water in the pail, the water will run through, and continue to do so till the pail is empty. A tube used in this way is termed a siphon, and forms a ready means of either filling or emptying an aquarium. The advantage in the former case over more rough and ready methods of filling aquaria is that a steady stream of water may be allowed to flow in without disturbing the plants or disarranging the sandy bed.

An aquarium fitted up as described will answer most but not all the purposes of the student of freshwater life. In it a great variety of creatures may be kept under almost perfectly natural conditions, and therefore observed to the best advantage. But, as we have already hinted, there are living objects so small that they would be lost in any moderately sized aquarium, and should therefore be kept in jars or other small vessels where they can be conveniently observed. Again, in ponds we meet with many creatures that are always to be found lying on or burrowing into soft mud. These should be kept by themselves in a vessel with a layer of mud from the pond from which they were taken.

Matters of this description, however, are so numerous that it would be impossible to deal with them here; but a careful observer at work in the field, who is in the habit of closely watching the habits of animals, and who endeavours to keep all his captives under conditions corresponding with those under which he found them, will have little difficulty in keeping and rearing all he requires.

The success of an aquarium depends to a considerable extent on the manner in which it has been started. If well fitted up, in the first instance, with a well-balanced proportion of animal and vegetable life, and constructed or shaded in such a way as to exclude extraneous light, then there is no reason why it should not remain in a satisfactory condition for a very long time without the slightest attention. But whether this is so or not, it is well to know that the successful and intelligent management of aquaria depends on the knowledge of certain of the principles underlying animal and vegetable growth. Perhaps the most important matter of all is the arrangement for the proper aëration of the water; and as this is a consideration of great moment to the aquarium keeper, we shall now study in detail the different ways in which the necessary amount of air may be maintained.

In the first place let us see what changes are produced in water as a result of the respiration of those creatures that obtain the whole or part of the air they require from the liquid in which they live.

If we put some water from any pond or stream or from any source of domestic supply into a test tube or small glass flask and then apply heat, we shall soon observe little bubbles of gas clinging to the sides of the vessel, and afterwards detaching themselves and rising to the surface. These bubbles consist of gases which have been absorbed from the atmosphere, and are principally composed of oxygen, nitrogen, and carbonic acid gas. The first of these is the great supporter of animal life, and is therefore the one which must be replaced as fast as it is consumed by the aquatic creatures. The other two, though not required by animals, are not in themselves objectionable to them; but the last is essential to the green aquatic plants, and will be presently considered in relation to their requirements.

FIG. 57.—HEATING WATER IN A TEST TUBE

The oxygen gas is absorbed in considerable quantities by the breathing organs of the truly aquatic creatures, and is used up in their bodies partly for the oxidation of waste carbonaceous matter, thereby giving rise to the formation of carbonic acid gas, which is being continuously passed into the water by the same organs that imbibe the oxygen. Thus the water is being continually deprived of its life-supporting gas, and is constantly gaining the useless (to the animals) product of oxidation formed by the union of carbon and oxygen.

If, then, fishes or other water-breathing animals are kept in a limited supply of water with no arrangement for the renewal of oxygen, it is plain that the water must sooner or later lose its power of supporting animal life, and disaster must follow. If the inmates of such an unsatisfactory aquarium include fishes, we are warned of the coming danger by their movements. Finding the bulk of the water powerless to supply them with sufficient oxygen to allow them to live in comfort, even when they considerably increase the rate of their respiratory movements by a much more rapid succession of gulps of water to bathe the gills, they instinctively rise to the surface, where the contact with the air allows oxygen to be slowly absorbed. So we see them skimming the surface, and gasping in their endeavours to secure a requisite amount of air.

Such a scene as this will suggest at once a remedy—run out all the water and introduce a fresh supply. But it is tiresome and in other respects unsatisfactory to be compelled to change the water

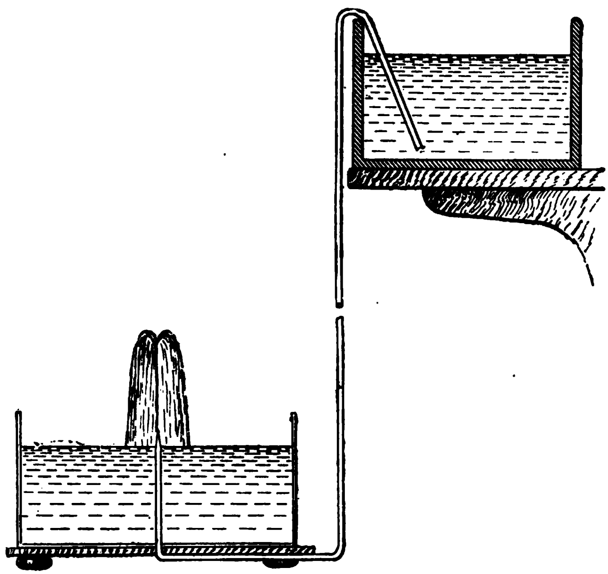


Fig. 58.—Arrangement for a Fountain in the Aquarium

at regular intervals, those intervals varying with the number of aquatic animals in proportion to the quantity of water. Other remedies will suggest themselves, such as keeping up a continuous current of water, or forcing air into the water by some mechanical contrivance. The former of these will probably be the more convenient plan in the hands of most amateurs, but both are commonly employed, and will therefore be considered.

Should the aquarium be situated near a water tap and a sink there will be no difficulty whatever in arranging for a constant current. Simply carry a pipe over the top for water to run in, and connect a waste pipe at the bottom or side to carry away the excess. The waste pipe should of course be larger than the supply pipe, in order that there may be no danger of overflow; and for the same reason the inner opening of the waste pipe should be covered with a hemispherical cap of wire gauze, otherwise it may be stopped by floating matter, such as a fallen leaf or the body of a dead fish; and the cap of gauze will also guard against the escape of the smaller living objects of the aquarium.

A little fountain at play in the middle of an aquarium not only has a very pretty effect, but is also one of the best means of carrying

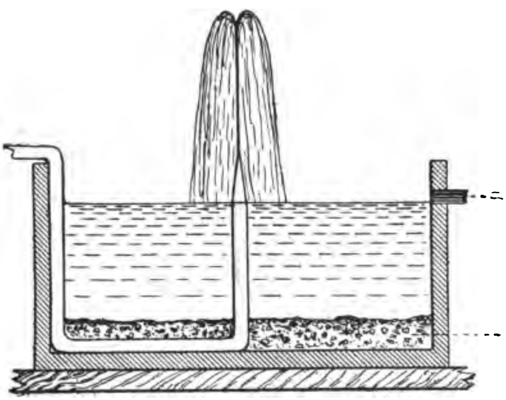


FIG. 59.—ANOTHER ARRANGEMENT OF THE FOUNTAIN PIPE

the necessary air supply into the water, for a fine jet of water, thrown into the air and broken up into a number of little globules, exposes so much surface to the atmosphere in proportion to its bulk that it falls saturated with oxygen.

The neatest way to arrange such a fountain is to bore a hole about a half or three-quarters of an inch in diameter in the middle of the base of the aquarium, and to fit in this a cork through which runs a tube that reaches to the surface of the water; and then to fix on the top of this a little jet made by drawing out a piece of glass tubing in a gas flame. The jet may be connected by means of a small piece of indiarubber tubing, while the tube projecting from the cork below is made to communicate with the water supply.

Should there be any difficulty in the way of boring a hole in the bottom of the aquarium, a piece of very small 'compo' gas piping may be bent over the top in one of the corners, and then carried to the middle of the bottom, from which point it should rise perpendicularly to the surface to receive the jet. This arrangement is shown in fig. 59.

It must be borne in mind, too, in connection with this method of aërating the water, that there is no need whatever of making any

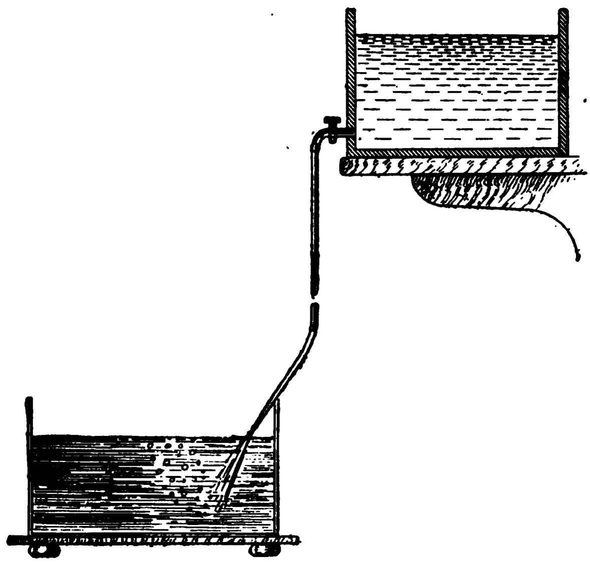


FIG. 60.—ANOTHER METHOD OF AËRATING THE WATER OF AN AQUARIUM

connection with the house supply, for water more or less deficient in oxygen may be taken from the aquarium, to which it is returned again after having been exposed to the air in the form of a fountain jet. A sketch illustrating one of the many ways in which this may be done is given on page 80. A jar or other reservoir provided with a tap or a siphon tube is placed on a shelf or preferably, quite out of sight in a cupboard, some feet above the level of the aquarium;

and the tap or tube, as the case may be, is securely connected with the fountain jet. Water may then be dipped from the aquarium and thrown into the reservoir, whence it returns with an increase of oxygen derived from the air.

In the case of public aquaria, air is often forced into the water by means of some kind of pump. This is all very well where the tanks are many and large, and where the cost of the necessary machinery is not a matter for consideration; but for the amateur with only one or two small tanks, this method is out of the question. But an equally good means of forcing air into the water is practicable on the smallest scale. Make a very fine jet by drawing out a piece of glass tubing in the gas flame, and connect this securely with a water supply in such a way that it points downward obliquely towards the centre of the aquarium. The pressure must be considerable, the house cistern or the improvised jar-cistern previously mentioned being several feet above the jet, and then the water rushing from the latter, which in this case must be above the level of the water in the aquarium, carries with it as it descends numerous little bubbles of air. It will be seen from what has been said that in this case, too, the water for the aërating jet may be taken from the aquarium itself if no other convenient supply be handy; moreover, if this method be adopted there will be no need for a pipe and sink for waste; but a fresh supply is always to be preferred if that in use shows any signs of becoming putrid or turbid.

We have now considered all the principal methods of maintaining the air supply in aquaria with the exception of *the best*, and that is by means of the influence of vegetable life. The process of respiration in plants is similar to that of animals, the plants inhaling oxygen, which is required for the oxidation of the tissues, and which is in part converted into carbonic acid gas. But in connection with the function of nutrition in green plants there are other changes in progress—changes which affect the composition of the atmosphere far more than those associated with respiration.

During the daytime large quantities of carbonic acid gas are absorbed by green vegetation. This is decomposed within the plant, the carbon it contains being added to the solid structures of the plants, and the oxygen being set free into the air or, in the case of aquatic plants, into the water. Thus the balance of the double action of plants, as affecting the composition of the air, is considerably against and opposed to that of animals.

If, then, animals diminish the proportion of oxygen in the air which they breathe, and add to the quantity of carbonic acid gas; and green plants, on the other hand, increase the amount of oxygen and reduce the carbonic acid gas, it is clear that a combination of animal and vegetable life in a certain proportion is capable of maintaining a constant composition of the atmosphere.

This is practically the case in nature, and a similar balance of life may be maintained in even the smallest aquaria by a judicious selection of animal and vegetable life.

Rules have been laid down in this matter for the guidance of young and inexperienced aquarium keepers, giving the number of animals of different kinds that may safely be kept in aquaria of certain capacities, and also the approximate amount of vegetation necessary to maintain the balance of life; but such rules are only approximate, and are not likely to aid a beginner half so well as his own observations.

However, in our endeavours to adjust the proportion of animal and vegetable life in the aquarium, we must be careful to distinguish between the true aquatic breathers and those which obtain their air direct from the atmosphere. The former include all fishes and aquatic molluscs, also the aquatic crustaceans, many insects, and numerous lower forms of life. But the introduction of some insects, such as water beetles, water bugs, &c., need not enter into the computation at all, for they rise to the surface for all the air they require. Newts also make no demand on the water for their oxygen except for the small amount absorbed through their soft and moist skins.

A careful observation of the aquarium will always suffice to show whether the balance of life is well maintained. If we find the death rate high, and observe the fishes skimming the surface of the water, we may be sure that the vegetation is inadequate for the production of the required amount of oxygen; and the introduction of a few more plants may set matters right. If, on the other hand, we find a very luxuriant vegetable growth, with a rapidly increasing quantity of foliage, and all the animals apparently at ease and thriving well, we may venture to make cautious gradual additions to the animal life, providing we carefully watch the results.

In all aquaria, whatever be the means employed for the aëration of the water, a certain amount of air will always be absorbed direct from the atmosphere; and, of course, the larger the area of the surface of the water, the greater will be the volume of air absorbed.

It will thus be seen that a broad and somewhat shallow aquarium has, in the matter of air supply, a decided advantage over one that is narrower and deeper. This difference, however, though always deserving of consideration, is not of great importance when the aquarium is well supplied with vegetable life. In fact, tanks may be managed with so little regard to this external means of aëration that they may even be covered with glass plates to exclude dust. But, personally, I am not inclined to recommend this; for as a rule but little dust floats about in places in which our aquaria are situated; and although they may be richly supplied with air apart from a direct atmospheric source, yet it is impossible to have too much, and it is also advisable to allow a perfectly free exit for any products of decomposition that may arise, however small the quantity may be.

We have one other form of aquarium to consider, and that—the garden pond—is certainly, in some respects, the best of all. It may not be, and in fact *is* not, so well adapted for carrying out close observations, especially in the case of the small creatures; but in it we can keep and rear a great variety of life under the most natural conditions, and so maintain a 'stock' from which we can always draw supplies for indoor aquaria when required, and from which we may select objects for special study at all seasons of the year.

For the study of aquatic plants, too, the garden pond is in every way satisfactory. In it we can grow those species which require much room, and those that will not flourish without plenty of soil. Semi-aquatic plants may also be cultivated on its banks, as well as the tall species which shoot high above the water and thus provide suitable resting places for certain aquatic insects when undergoing their final metamorphoses, and while they exist in the perfect state.

The formation of a garden pond is not at all a difficult matter, and the work entailed will afford some vigorous and healthy exercise.

The size will of course depend on the space at disposal and the amount of manual labour forthcoming; and, this matter being settled, the first thing is to dig out the bed, to a depth of three or four feet in the middle, with sloping banks.

The next thing is to make the bed impermeable to water, and this may be done either by means of clay or cement.

If clay is used it should be free from stones, and it should be well worked or 'puddled' till in a suitable condition for laying on the bed. The puddling is a matter of great importance, for the more thoroughly this is done the more impermeable will be the bed.

Cement has the advantage of cleanliness. A bed of this material can be thoroughly washed out when occasion requires, and the layer of soil on it may be renewed as it becomes exhausted.

All the methods of aëration employed in indoor aquaria may be applied to outdoor or conservatory ponds, but nothing can possibly be more effectual than the introduction of a suitable amount of vegetable life. A fountain issuing from the summit of a central rockery, relieved by the graceful fronds of ferns or the foliage and flowers of semi-aquatic plants, will also add to the beauty of the pond as well as to the air supply of its water.

But apart from the consideration of air supply there is little fear of any but a very small pond becoming foul, for the surface exposed to air is so large as a rule in proportion to the volume of the water, that sufficient oxygen for the support of any reasonable amount of animal life may be obtained almost exclusively by absorption direct from the atmosphere.

It will hardly be necessary to inform the reader that, when the water from a fountain jet is more than sufficient to make good the loss by evaporation, it will be essential to have a properly constructed drain pipe to carry off the excess, and so prevent the banks from becoming wet and marshy.

We will now give a little consideration to some of the species of plants that are likely to prove useful to the aquarium keeper.

Among the best known of our pond plants are the pretty little duckweeds (genus *Lemna*) that so often completely cover the water with a bright green mantle. They are floating weeds, requiring no soil of any kind, but deriving all their nourishment from the water by means of long and slender roots. They increase very rapidly by budding and also from seeds, but principally by the former method. Their flowers are developed on the under side of the frondlike leaves, and consist of a pistil and one or two anthers, enclosed in a very small membranous sheath.

There are four British species of the genus, the smallest of which—the Lesser Duckweed (*Lemna minor*)—is the one most commonly seen on the standing pool. The Ivy-leaved Duckweed (*L. trisulca*) is very much larger, but far less common. It is so named on account of its three-lobed fronds, which somewhat resemble miniature ivy leaves in form.

These little plants are really valuable at times in the aquarium or garden pond, particularly when the water is more or less exposed to direct sunlight, for they serve to keep the water cool, as well as to afford the darkened shelter which so many aquatic creatures love; but, being very prolific, it will often be found necessary to keep them within bounds by occasionally skimming off the excess.

FIG. 61.—*Lemna trisulca*

The American Pondweed (*Anacharis Alsinastrum*) is another very useful plant, suitable for aquaria and ponds of all sizes. It is a Canadian plant, and was introduced into Britain by some unknown means about the middle of the present century. Its appearance in several parts of the country was almost simultaneous, and from the time of its introduction it has flourished so luxuriantly and extended so widely that many streams and canals have been almost completely blocked by it. This rapid extension over so many districts remote from each other has been, and still is, a great puzzle to botanists. If light fertile seeds which could be carried here and there by the winds were developed by the plant, no further explanation would be needed; but it so happens that the weed is *diœcious*—that is, the male and the female flowers are borne on separate plants—and the pistilliferous (female or pistil-bearing) plants only have been found in Britain. Hence it follows that the *Anacharis* must have been propagated entirely by buds.

FIG. 62.—THE AMERICAN POND-WEED (*Anacharis Alsinastrum*)

It is a very hardy plant, and though it is attached to the soil of streams and canals by roots, yet it seems to thrive equally well in the aquarium without any soil at all, and a few fragments simply thrown into the water in the summer time will soon produce a thick mass of branching stems thickly set with whorls of small leaves, usually three in number.

In the indoor aquarium *Anacharis* keeps beautifully green all the year round, and it appears to be a splendid generator of oxygen. It is also very valuable as a food for fishes, many of which are very fond of nibbling away at the young leaves. I have found it extremely useful for maintaining a condition of purity in small glasses or bottles where the smaller species of aquatic animals are kept for some time under close observation.

Fig. 63.—The Hornwort (*Ceratophyllum demersum*)

The Hornwort (*Ceratophyllum demersum*) also is a valuable oxygen generator, and is extremely hardy as well, and requires no soil. It is a floating weed, deriving its nourishment, like the duckweeds, entirely from the water, and is common in ponds and slow streams.

Its leaves are long and slender and generally forked, and are arranged in whorls round the stem.

The flowers are very small and inconspicuous, the male and female blooms being distinct. The former consists of a number (about fifteen) of sessile anthers surrounded by a whorl of very small bracts, and the latter of a small one-seeded ovary similarly surrounded.

Fig. 64.—*Vallisneria spiralis*

This plant—the only one of its genus—is a very pretty ornament in the aquarium.

Vallisneria spiralis (fig. 64) is a most copious oxygen generator, and on this account it has become very popular among aquarium keepers. This plant is not a native of Britain, but is plentiful in many parts of South Europe.

Its inconspicuous stem is perennial, and bears a number of very long and narrow grasslike leaves.

The plant is *diœcious*, like *Anacharis*, and is remarkable for the manner in which the fertilisation of the seeds is effected.

The female flowers have a cylindrical ovary, on the top of which is a three-lobed calyx, and three large oval stigmas; and they are mounted on very long and slender stalks which are twisted into the form of spirals, and which are so long that the flowers float on the surface, the spiral lengthening as the water rises.

The male flowers are very small, and are mounted on short stalks at the base of the plant. They are white, and in form globular, and consist of one, two, or three stamens, surrounded by a three-parted calyx.

When these flowers reach maturity they become detached and rise to the surface. The calyx then expands, and they float about among the female flowers, thus allowing the pollen grains to come in contact with the stigmas.

The fertilisation having thus been effected, the spiral stalk contracts till it is formed into a compact cylinder, pulling the female flower to the bottom; and within the cylinder the seeds are ripened.

The pretty Water Crowfoot (*Ranunculus aquatilis*) is deservedly a favourite for the aquarium. Although almost always found in water with a muddy bottom, yet it grows well in aquaria with no other soil than a layer of sand.

FIG. 65.—*Ranunculus aquatilis*

The leaves of this plant are of two distinct kinds, which we may term the submerged and the floating. The former are really long narrow tubes, arranged in such dense feathery clusters and often growing so fast as to fill the pond or tank with a tangled mass of green threads.

The floating leaves are broad and lobed, and lie horizontally on the surface.

The flowers are exceedingly pretty, and stand out of the water on erect stalks. They are of a pure white colour, with a cluster of many yellow stamens in the centre.

Sometimes the Water Crowfoot is to be seen in rather rapid streams, but in this case it develops no flowers or floating leaves, and is thus only a mass of waving green threads supported on long and flexible stalks.

There are a number of aquatic plants, forming the genus *Potamogeton*, commonly known as Pondweeds. They are very pretty plants, even though their flowers are green and inconspicuous, and they are exceedingly useful as oxygen producers in the aquarium.

The members of this genus—more than a dozen in number—are all fragile plants, sometimes floating on the surface, and sometimes fixed to the soil by their roots; and representatives are to be seen in almost every pond, large and small. In canals and sluggish rivers, too, they sometimes flourish so profusely that the stream is

FIG. 66.—*Potamogeton natans*

FIG. 67.—*Potamogeton densus*

almost choked; and in the autumn, when they shed their leaves, the quantity of vegetable matter carried into the sluices of mills often causes much damage and delay.

The flowers have both stamens and pistil, and all the parts are arranged in fours—the perianth four-cleft, four stamens, and four seed-vessels.

FIG. 68.—*Potamogeton perfoliatus*

FIG. 69.—*Potamogeton crispus*

FIG. 70.—THE LONG-LEAVED PONDWEED (*Potamogeton fluitans*)

Perhaps the commonest species is the Broad-leaved Pondweed (*Potamogeton natans*), the floating leaves of which are elliptical, while the submerged leaves are long and narrow. Ponds and portions of sluggish rivers may often be seen so densely covered with the olive-tinted floating leaves of this weed that hardly a patch of water is visible.

Other species, such as the Close-leaved Pondweed (*P. densus*), the Perfoliate Pondweed (*P. perfoliatus*), and the Curled Pondweed

FIG. 71.—THE VARIED-LEAVED PONDWEED (*Potamogeton heterophyllus*)

FIG. 72.—THE SHINING PONDWEED (*Potamogeton lucens*)

FIG. 73.—THE FLAT-STALKED PONDWEED (*Potamogeton compressus*)

(*P. crispus*), have no floating leaves. These, together with a few other British species, are here figured.

FIG. 74.—THE FENNEL-LEAVED PONDWEED (*Potamogeton pectinatus*)

FIG. 75.—THE SPEAR-LEAVED PONDWEED (*Potamogeton lanceolatus*)

The Starwort (*Callitriche verna*) is a very pretty aquarium plant. Its popular name has been given to it on account of the star-shaped clusters of leaves on the summits of the stems. The flowers are usually unisexual. They are very small, green, and situated in the axils of the leaves. The male flowers consist of a

FIG. 76.—THE GRASSY PONDWEED (*Potamogeton gramineus*)

FIG. 77.—THE WATER STAR WORT (*Callitriche verna*)

single stamen between two bracts. The female flowers, which are very similar in general appearance, have a six-lobed ovary with two curved styles.

The reader will probably meet with many other aquatic plants during his excursions, and any of them may have a trial in the

FIG. 78.—THE YELLOW WATER LILY (*Nuphar lutea*)

FIG. 79.—THE WHITE WATER LILY (*Nymphæa alba*)

FIG. 80.—THE SWEET FLAG (*Acorus calamus*)

aquarium. Some there are that require plenty of soil, and when these are chosen there should always be a moderately thick layer of soil, under the sand or gravel, from which they may derive nourishment.

Then, in addition to the British species, a number of foreign plants (one of which has been already mentioned) have been imported by dealers in aquaria and aquatics, and some of these are deservedly popular.

Again, we have many aquatic plants of such large size that they are suitable only for large tanks and ponds. Foremost among these are the beautiful Water Lilies.

The common Yellow Water Lily (*Nuphar lutea*) is to be found in most parts of Britain. It is commonly known as the Brandy Bottle on account of the peculiar spirituous perfume of its flowers. The White Water Lily (*Nymphæa alba*), also common in our lakes, is interesting on account of its habits of closing its petals and drooping its flowers at night.

A garden pond may be further ornamented by means of a selection of semi-aquatic flowering plants, though these are not of so

FIG. 81.—THE FLOWERING RUSH (*Butomus umbellatus*)

FIG. 82.—THE GREATER WATER PLANTAIN (*Alisma Plantago*)

FIG. 83. — THE LESSER WATER PLANTAIN (*Alisma ranunculoides*)

much service in maintaining the supply of oxygen in the water. Perhaps the best way of managing these, in the case of small ponds, is to plant them in ordinary flower-pots, and then conceal the pots in the midst of an artificial rockery so that they are partially submerged. In this way the banks of an artificial pond may be adorned with Sweet Flags, Flowering Rushes, Water Thyme, Arrowheads, Water Plantains, and many other really beautiful plants.

Now let us suppose the aquarium complete and well established. Everything is going well. The animals are apparently living in the greatest of comfort. The measured and graceful movements of the fishes show that all must be right. They give no evidence of a lack of oxygen by gasping for air at the surface of the water. The aquatic plants too, we suppose, are growing well. Their foliage is beautifully green, and some are already showing flower.

With such favourable symptoms as these we may certainly regard the affair as a complete success, but this must by no means be taken as a guarantee that all will *continue* to go well, and that the aquarium needs no further attention.

In fact the reverse is the case. Sooner or later your services will be required to restore a balance of life. Some of your plants will grow so wild and so profusely that the aquarium will bid fair to become an almost impenetrable mass of entangled weeds. Duckweeds may increase so rapidly that nothing beside them is to be seen. Green slimy freshwater sponges may form dense unsightly floating masses. Occasionally a fish or other creature will die, and the corpse, if not removed, will soon decompose and render the water putrid.

With such possibilities as these, it behoves the aquarium keeper to be always on the alert, especially in hot weather, when both growth and decay proceed with great rapidity.

It may not be amiss now to deal briefly with a few of the disorders to which the aquarium and its inmates are liable, and to consider the best means of restoring order and equilibrium.

One who keeps a bell aquarium after the ordinary fashion, with no soil and no plants, must necessarily change the water at frequent intervals in order to renew the air. In such a case, therefore, stagnation is impossible, and fungoid and confervoid growths stand no chance of a firm hold. The owner may claim this advantage over another who endeavours to maintain the supply of oxygen by the introduction of plant life; but the latter would hardly care to keep his aquarium in such an unnatural manner, to say nothing of the loss of the picturesqueness afforded by the beautiful aquatic plants, and the daily trouble, under a heavy penalty, of emptying and refilling.

The aquarium that is once balanced by a proper adjustment of animal and vegetable life *may*, and certainly *does*, require an occasional overhauling, but the occasions are few and far between; and the warnings given to a careful observer are so gradual in their appearance that he is never compelled to set about the task in haste or at inconvenient times. If the aquarium *begins* to look turbid, or the confervæ commence to settle on the glass, the owner knows that, as a rule, a week or so may still run on with perfect safety to the inmates; and the glass itself may be so thickly covered with confervoid growths that nothing can be seen through it, and even then the inmates be none the worse, but may be even better off than when everything is perfectly clear and transparent. On the other hand, the keeper of the unnatural bell aquarium is compelled to change the water at frequent intervals; and a single act of forgetfulness or a few hours' pressure of business may cause him the loss of his entire stock.

We have already stated that the spontaneous growth of low forms of green vegetation is greatly accelerated by strong light, and may therefore be retarded by subduing the rays by the interposition of a screen of paper. If the vegetation is already dense, a temporary darkness will reduce it. But this method of effecting a partial cure is objectionable, for the light-loving creatures in the aquarium are kept in darkness for a few days at least, and even then the vegetable growth is not destroyed, but only stunted, and is ready to develop with renewed vigour as soon as the vivifying light breaks on it.

When the transparency of the aquarium is much impaired by the growth of confervæ, it will be as well to determine on a thorough cleansing of the glass, and of course a change of water; and this may be done without the necessity of removing any of the living things—animal or vegetable—save those which it is desired to move.

Run out water with a siphon till only a few inches remain, and then clean the glass with a little mop made by tying a pad of rag on the end of a stick. If any of the deposit is so obstinate as to refuse this kind of entreaty, dip the wet rag in very fine sand and apply again.

In a minute or two the vegetable growth will be quite removed, but the water remaining in it will be green and dirty. Start the siphon again, and at the same time allow clean water to run in from a can or pail, through another siphon of the same diameter. In this way you get a constant stream through the aquarium, so that, in a few minutes, if the siphon tubes are sufficiently large, all traces of floating vegetable particles, together with the miscellaneous sedimentary matter that always collects in an aquarium, are effectually carried away. The aquarium is now refilled, and everything is as bright and fresh as when it was first started.

Some of the freshwater univalve molluscs are greedy devourers of vegetables, and attack both the flowering plants and the low forms. Of these the larger species of the genus *Planorbis*, especially *P. corneus*; and *Stagnalis*, *Peregra Auricularia*, and others of the genus *Limnæa*; also *Paludina vivipara*, have all been recommended to aquarium keepers as a check on the growth of plant life.

Some of the above deliver their attacks principally on the flowering plants, while others crawl over confervoid deposits, devouring as they proceed. The former are of no very valuable aid as scavengers, for even if the plants increase at too rapid a rate, the excess can be easily removed; but those which attack the lower forms certainly do a useful work. Nevertheless I believe the value of these little window-cleaners has been much over-estimated. Twenty or thirty of them in a small ten-gallon aquarium fail to cope with the rapid development of confervæ in hot weather, even if the glass has a northern aspect. In fact, they seem to have but a slight influence on the rapid growth of these minute plants.

We have now to deal with a much more serious growth, but one which will never show itself except in the case of the most extreme neglect. I refer to a growth of a fungoid nature, of a whitish rather than a green colour, which attacks living fishes and other creatures.

The presence of this form of plant life frequently denotes a deficiency of light, and must *always* be regarded as a sign of the presence of decomposing organic matter, and therefore is a proof that the water is in a poisonous condition.

The aquarium gradually becomes turbid, just as if a little milk had been thrown into the water; and fine white threads may be seen radiating in patches on the surfaces of various objects, both lifeless and living. A faint but unpleasant odour may also be distinguished; and, if deaths have not already occurred among the inmates, heavy losses may be expected almost immediately unless the sanitary condition of the aquarium is rendered satisfactory.

Now, before taking up the cure for this state of things, let us inquire into the cause.

The fungoid growths to which I have alluded are the outcome of an exuberance of decomposing nitrogenous organic matter, and this may have been due to neglecting to remove the body of a dead fish or other animal. Perhaps, however, a more common cause is due to too much attention rather than neglect. It is a common practice with amateurs to give the animals in an aquarium a great deal more food than is necessary for their immediate wants. Worms, gentles, and other animals are thrown in rather thoughtlessly for the newts, beetles, or fishes; and those which are not devoured soon die, and then decomposition sets in.

Of course the warmer the water the more rapidly the decomposition and the resulting contamination proceed; and hence the necessity of being more watchful over the condition of aquaria in summer than in winter.

Again, while considering those circumstances which tend to cause such harmful conditions, it will be well to remember that certain aquatic creatures feed on *dead* organic matter, and consequently become most useful as scavengers.

Among the molluscs, *Limnæa pereger* and the little animals belonging to the genus *Pisidium* are very useful in this respect; and, all being of a very hardy nature, there need never be any difficulty in maintaining an efficient scavenger corps to work for the general welfare of the community.

Freshwater shrimps, which are generally abundant in small streams, are also hardy lovers of high game, and to these may be added the majority of aquatic beetles as well as young tadpoles; but it must be remembered that the former are very voracious creatures, always ready to attack the unarmed and defenceless living as well as the dead, and that the latter are highly appreciated by newts and many of the fishes and aquatic insects.

But now supposing that, notwithstanding our most careful endeavours to prevent those conditions which lead to a general putridity and its consequent fungoid growths, the aquarium reaches this undesirable state, what remedy shall we apply?

In considering this question we must remember that oxygen gas is the great natural destroyer of dead nitrogenous organic matter. An excess of this gas tends to decompose the unstable nitrogenous compounds, converting them into simpler and less harmful substances which are readily absorbed by growing vegetation, and in fact form valuable plant foods.

A constant stream of air or well-aërated water entering the aquarium may therefore do much to improve the sanitary condition; but perhaps, after all, nothing is so safe as a complete change of the water, produced either by emptying and refilling the vessel, or by a prolonged circulation brought about by a continuous supply of fresh water, with a waste pipe to prevent overflow.

I have just referred to temperature in relation to its effect in accelerating or retarding the decomposition of organic matter, but there are other reasons for regarding temperature as a factor on which success depends. On the one hand we must carefully avoid excessive heat, for the warmer the water the less is its capacity for dissolving gases and retaining them in solution; and, seeing that the gill-breathers are almost entirely dependent on the oxygen which the water holds in solution, this becomes a very important consideration.

On the other hand we have to avoid extreme cold; not that a freezing temperature is likely to do any harm to those creatures which in a natural state survive the winter, but because the freezing of a considerable volume of the water is likely to exert sufficient expansive power to force out the sides of the aquarium.

I have often seen my fishes so entangled among plates of ice running through the aquarium in all directions that they could not move far for several days, and yet the return of a more genial temperature showed that they had suffered little or nothing through the temporary confinement.

I have also frequently seen frogs and newts, enticed from their hiding-places by a spell of warm weather very early in the spring, and afterwards overtaken by a severe frost, completely embedded in a solid mass of ice for a week or more, with not the slightest power of moving, and yet, on the melting of the ice, they seemed none the worse.

Nevertheless such extremes should be avoided as much as possible, not only for the comfort of the creatures concerned, but to lessen the risk of damage to the vessel.

There is just one more matter for brief consideration—the nature of the food required by our various pets. Some allusion has already been made to these, so I will simply give a brief summary with a few additions.

Fishes partake largely of certain pondweeds, particularly the young buds and tender shoots of the plants to which I have already referred. They should also be supplied, in strict moderation, with *very small* earthworms, gentles (larvæ of the meat-fly), 'blood worms' (not really worms, but the larvæ of a fly), caddis larvæ, and 'ants' eggs' (not eggs, but the pupæ of ants).

Frogs and toads should be supplied with small beetles, worms, caterpillars, &c.; and newts with earthworms.

The carnivorous insects will partake readily of all kinds of animal matter; and tadpoles, molluscs, and most other aquatic animals will find all they require in an aquarium which is well supplied with weeds.

PART II

LIFE IN PONDS AND STREAMS

CHAPTER VI

LOWER FORMS OF POND LIFE

HAVING now dealt with the practical portion of the pond-hunter's work, I shall devote the remainder of this work to a description of some of the various species that may be met with during his excursions.

In those cases where an important group of animals is represented in our ponds and streams by only a few species, I shall describe all or nearly all of them. In many instances, however, scores, and even hundreds of aquatic creatures are included in one single order or family, and in dealing with such as these we shall be obliged to confine our attention to a few typical species.

The lower forms of animal life are very well represented in stagnant and running waters, and the young naturalist who devotes his attention to aquatic life will generally be able to find plenty of these to occupy his attention when the more complicated forms are scarce; but he will not be in a position to study these lower forms unless he is provided with a fairly good compound microscope.

This being the case, and seeing that it would be impossible to treat at all fully of microscopic pond life in the small space at my disposal, also considering the probability that many of my readers may never possess a microscope suitable for the purpose, I shall only select a few types of the lower divisions of animals, sufficient to enable the reader to know and understand the general characters of the larger groups, and thus to put him in a position to know what he is examining, and to locate his specimens in their proper position in the scale of life.

The Protozoa

The lowest forms of animal life are those which comprise the sub-kingdom *Protozoa*. They are mere minute specks of a living gelatinous substance called *protoplasm*, sometimes exhibiting no trace of any variation in their structure, having no special organs of any kind, not even so much as a covering without or a cavity within. They possess not the slightest trace of a nervous system; but though they have no organs of special sense, they may be capable of experiencing general sensations.

If you examine a drop of water taken from a small stagnant and muddy pool, you will probably find it teeming with microscopic life, some forms moving about so actively that it is difficult to keep them for any length of time within the field of the microscope when a high power is being employed, and others creeping lazily along on the surface of the glass slip.

Among the latter you may observe little gelatinous bodies of variable form and size, perfectly clear and transparent around the edges, but otherwise dotted with little granules of a darker substance.

As you watch them you see portions of the body thrust forward, first on one side and then on another. At first these projections are perfectly clear, being formed by extensions of the outer portion of the body; but as each one becomes longer, the granular substance suddenly rushes into it. These prolongations are temporary feet, which are capable of being thrown out from any part of the body, and by means of them the little animal slowly drags itself along in a perfectly aimless manner, the direction of its course being changed at almost every movement.

FIG. 84.—THE *Amœba*, HIGHLY MAGNIFIED

This little animal is called the *Amœba*, and is interesting as belonging to the very simplest of all living beings; but although so simple, it is a most interesting study for those who have a sufficiently high magnifying power for the observation of its various movements.

Sometimes we see within its body a number of little spaces filled with water, and also a little cavity which contracts and dilates in such a manner as to suggest a function similar to that of the heart of a higher animal; but this cannot be the case, for the *Amœba* has no blood-vessels, and no blood to circulate.

Within its body we may also observe a round or oval mass of a denser structure than the rest of the body. This is called the *nucleus*, and occasionally we find more than one of these in the same animal.

Like all other animals, the *Amœba* requires nourishment, for not only does every movement imply a certain amount of waste tissue that must be renewed, but it has also to propagate its kind.

But how can it feed, seeing that it has no mouth to receive food and no stomach in which to digest it? This question can be readily answered by observing the animal under a high power.

FIG. 85.—THE *Amœba* FEEDING, THREE STAGES ILLUSTRATED

The water in which it lives always contains minute animal and vegetable organisms, much smaller even than the *Amœba* itself; and these, and especially the vegetable organisms, constitute its food.

The *Amœba* has no power to make direct for its food, and does not seem to be aware of its presence even when very near it, but meets with it in an accidental kind of way during the course of its erratic ramblings. When, however, it comes into actual contact with a suitable morsel, it slowly surrounds it by means of the temporary prolongations of its body.

The body of the *Amœba* being very transparent, the gradual digestion of the morsel can be watched without difficulty; and it is interesting to note that the indigestible residue is cast out through a temporary opening in any part of the body.

Amœbæ may be found in stagnant water at all times of the year, though they are far more abundant during the warmer months. In very cold weather they become very inactive, but resume their movements on the apprcach of a more genial temperature.

Another interesting feature in the life history of the *Amœba* is the manner in which it propagates its species. The nucleus gradually elongates, becomes constricted in the middle, and then divides into two. The body itself then follows suit, and divides completely with one of the two nuclei in each, thus forming two distinct individuals, each of which proceeds on its own way.

It is not necessary to search ponds and ditches in order to find *Amœbæ*, for they may be cultivated at home with the greatest of ease. Simply pour some boiling water on hay or other vegetable matter, and allow the infusion thus formed to cool. Leave it out of doors in an open vessel for a few days, and then remove a drop by means of the dipping tube, transfer it to a glass slip, cover with a cover glass, and examine it under a high power.

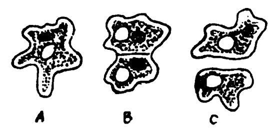


FIG. 86.—*Amœba* DIVIDING

A, before division; B, dividing; C, after division

The infusion will be found to be full of life, the result of the rapid development of germs that have been carried into the vessel by the movements of the atmosphere, and the subsequent extremely rapid multiplication of the beings produced.

Among the creatures thus provided with a home we may find *Amœba*, but by far the larger number will consist of little beings which exhibit the most lively movements, some darting and rolling about in a most erratic manner, while others, though fixed to solid objects or otherwise stationary, yet maintain a rapid motion of parts of their bodies.

The animals to which we refer are generally known as *Infusorians*, since they so readily make their appearance in infusions of animal and vegetable substances; but they may also, like the *Amœba*, be found in stagnant pools and ditches throughout the whole of the year.

In many respects they resemble *Amœbæ*, being very simply formed, consisting of a single gelatinous cell, and they also multiply by division of their bodies.

Their bodies are provided with very minute hairlike projections, sometimes arranged in definite lines on certain parts only, and sometimes distributed equally or nearly so over the whole surface.

These little hairlike projections (called *cilia*) are kept in a rapid vibratory movement, and the vibrations are frequently so rapid that they are quite invisible. It is by this means that the *Infusoria* move so quickly through the water, or, in the case of the fixed species, keep up a rapid circulation of water round their bodies.

One of the commonest of the *Infusoria* is *Paramœcium*, commonly known as the Slipper Animalcule, from the slipper-like form of its body. It is surrounded by a thin and somewhat firm structure that serves the purpose of a skin, and this gives rise to hundreds of cilia scattered over its whole surface.

The motion of this animalcule is very curious, being a combined onward and revolving movement.

It has a funnel-shaped depression on one side of its body, and the mouth of the funnel is richly supplied with cilia, the function of which is to produce water currents that will carry food particles into the depression. This depression therefore serves the purpose of a mouth; but the indigestible particles of food are expelled in the same manner as with the *Amœba*.

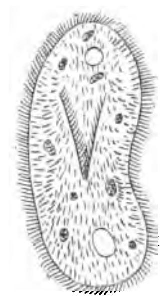


FIG. 87.—THE SLIPPER ANIMALCULE (*Paramœcium*), HIGHLY MAGNIFIED

The different species of *Paramœcium* may be found in almost every pool during the greater part of the year, even in the depths of winter. Like many others of the *Infusoria*, they seek shelter among the confervoid growths; and if a little of this vegetation be taken home in a small bottle, together with some water from the same pool, plenty of interesting microscopic work will be forthcoming. They are very variable in size, ranging from about one-hundredth to one-thousandth of an inch in length.

As an example of the fixed *Infusorians* we will take the beautiful *Vorticellæ* or Bell Animalcules, of which several species are to be found in ponds, sometimes in such numbers as to form a whitish film over the fronds of the duckweed.

This animal is of the form of a minute wineglass, varying from one-hundredth to one-, three-, or four-thousandth of an inch in length, mounted on the top of a longer and exceedingly slender stalk. The rim of the wineglass, or bell, as it is more commonly called, is thickened and turned outward, and fringed with a circle of minute cilia.

It is also provided with a cover which is capable of being lifted like the lid of a box, and between the lid and the rim on one side there is a funnel-shaped depression which runs to the middle of the bell, and serves the purpose of a mouth and œsophagus.

As in *Amœba*, the outer part of the body is clear, while the inner portion is dotted with little granules of a dark substance; and the nucleus, which is still more granulated, is elongated, and curved into the form of a crescent.

In order to watch the movements of *Vorticella*, place one or two fronds of the duckweed to which they are attached in a live-box, and, having found a cluster, watch them steadily under a moderate power.

As you look at the cluster, observing the very rapid movement of the vibratile cilia, and the floating particles that give evidence of the water currents which the cilia produce, you notice now and again that one of the animals very suddenly disappears; too suddenly, in fact, for its motion to be watched. But a little closer

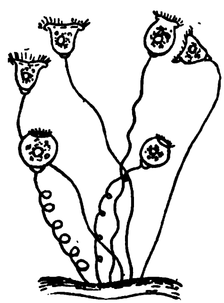


FIG. 88.—A GROUP OF *Vorticellæ*, MAGNIFIED

FIG. 89.—A SINGLE *Vorticella*, AS SEEN UNDER A HIGHER POWER

attention reveals the *Vorticella* in its new position. Its stalk has coiled up into a spiral with amazing rapidity, thus bringing the bell close to the base of the stalk.

At the same time the rim has turned in so that the bell has assumed a globular form, the lid has also been enclosed, and all the cilia have disappeared.

Slowly it resumes its former position and activity. The stalk gradually straightens out, the bell opens, the lid gapes, and the cilia vibrate continuously.

So all the Vorticellæ of the cluster go through the same performance in turn, even though undisturbed, as if a brief period of rest were necessary at very short intervals. But now give a smart tap on the table which supports the microscope, and the whole group simultaneously retreat in the same manner as before.

There are several species of *Vorticella* to be found in our ponds. Most of them are perfectly colourless, but others are tinted with green. All are so transparent that the process of digestion and the rhythmic contraction of a vesicle can be seen distinctly.

Particles of food are carried into the mouth by means of water currents set up by the cilia; and after the digestible matter has been extracted, the insoluble refuse is cast out through a temporary opening in the body.

We have seen that the *Amœba* multiplies by a simple division of its substance. This is true also of *Vorticella,* which divides into two by a longitudinal fission. It also multiplies by means of germs, which are formed by the breaking up of the crescentic nucleus, and which are afterwards ejected into the water, provided with their own means of locomotion.

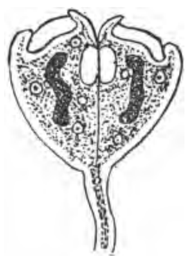


FIG. 90.—*Vorticella* DIVIDING LONGITUDINALLY

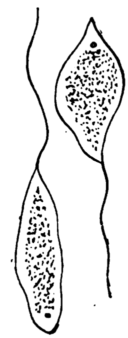


FIG. 91.—*Euglena*

Sometimes a *Vorticella* may be seen to contract into a ball, and to develop a firm gelatinous covering completely round itself. It is then said to be encysted, and in this state it passes a longer or shorter period of perfect inactivity. But this is only a temporary rest, and after a time the animal emerges again and resumes its former condition and habits.

Some of the *Infusoria* have only one or two long whiplike cilia, and these form a distinct division known as the *Flagellata.* One of these, called *Euglena,* is often to be met with in stagnant water and in infusions. It is particularly interesting on account of its varied movements and almost constantly changing form, and perhaps still more so on account of the controversies between zoologists as to whether the being is an animal or a plant.

It contains green colouring matter, apparently identical with that of plants; and the fact that it can move about is not sufficient in itself to prove that it is not a plant, for motion and even locomotion is not at all an uncommon phenomenon in both unicellular and multicellular plants. But the nature of its food and the manner in which it is taken seems to point to a place in the animal kingdom.

Plants possess the power of breaking up water, carbonic acid gas, ammonia, and other inorganic fluids, and of building up complicated organic compounds with their elements. Animals, on the other hand, cannot subsist on such inorganic foods, but select their diet from organic compounds that have already been built up in the laboratory of some animal or plant; and if we are willing to accept this feature as a satisfactory distinguishing characteristic between the two great kingdoms into which living beings are divided, then we must undoubtedly place *Euglena* on the animal side, for it feeds like *Amœba* and *Vorticella*, enclosing organic solids within itself, and digesting them by the action of the fluids of its own body; but on whichever side we place it, we are bound to admit that *Euglena* is at least very near the borderland between animals and plants.

It is very interesting to watch the movements and habits of *Euglena*. Both its body and its 'tail' or 'whip' are constantly varying in form, the former becoming swollen first in one part and then in another, and the latter assuming all kinds of shapes, and sometimes disappearing altogether. At times the whole becomes quiescent, assuming a globular form, and looking just like a simple vegetable cell.

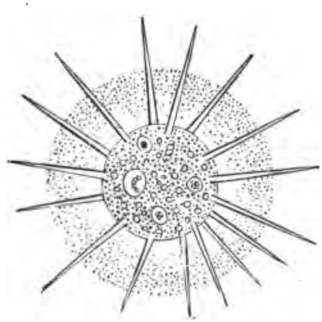


FIG. 92.—*Actinophrys sol*, HIGHLY MAGNIFIED

I shall briefly mention and figure two other species, mainly with the object of showing that they include a variety of forms, some of which are extremely beautiful objects when seen under a good microscope.

The first of these is the Sun Animalcule (*Actinophrys sol*), a globular species, with long tapering cilia distributed over the whole of its surface, thus reminding us of the glorious sun and his rays. It is to be found among the confervoid growths in stagnant ponds and pools. The other is *Stentor*, a funnel-shaped animalcule, the largest of all the *Infusorians*, with a wreath of cilia at the large end. The Sun Animalcule attaches itself to pondweeds, but Stentor swims about actively, and has the power of contracting its body into an oval mass during its periods of rest.

FIG. 93.—*Stentor*

Let us now leave the Animalcules—representatives of the lowest sub-kingdom of the animal world—and pass on to the *Polystomata* or Sponges.

It may probably surprise some of my readers to learn that sponges are to be found in ponds and streams of fresh water. The word 'sponge' recalls an image of the common toilet sponge, which is really the porous and fibrous skeleton of a marine species, and it reminds us of diving and dredging in warm seas. Nor is it generally known that we have sponges in plenty on our own shores; but we must say nothing of these, for we have to confine our attention to two freshwater species—the common River Sponge (*Spongilla fluviatilis*), that covers the banks of rivers and canals, and forms a greenish slimy crust on floating or submerged timber; and the Pond Sponge (*S. lacustris*), which may often be found in abundance in ponds and lakes.

Sponges form the sub-kingdom *Porifera*, also known as the *Spongida* and the *Polystomata*. The first of these names signifies 'hole-bearing,' and the last 'many openings'; and both serve to denote the most important character of the group, for sponges exhibit a number of holes on their surface.

The larger holes are the openings of canals which penetrate into the sponge mass, and there they divide and subdivide, giving off smaller and smaller branches, the smallest of which also open on the surface. Thus the mass is provided with a complete system of tubes for the circulation of water, which is always flowing in through the small apertures of the living sponge and escaping through the larger ones. The larger openings are usually situated on the summit of slight conical projections, which give an irregular appearance to the sponge mass and look somewhat like so many little volcanoes.

The skeletons of sponges generally consist of a fibrous and horny material, intermingled with which are little 'spicules' of silica that have grown into all manner of curious shapes, often resembling familiar objects, such as pins, axes, crosses, hooks, anchors, &c. In some cases the entire skeleton is formed by spicules alone, while in others there is a framework of calcareous substance.

FIG. 94.—SPICULES FROM VARIOUS SPONGES

The animal itself consists of a layer of cells which completely cover the skeleton, and may be compared to a colony of *Amœbæ*. Many of the cells, however, are provided with cilia, and it is by the vibration of these cilia that the water currents previously mentioned are produced. Each cell is thus supplied with both air and food, the welfare of all being brought about by the combined action of many individuals.

Sponges grow by an increase in the number of cells brought about by a continuous budding; and they are capable of multiplication in two or three ways. They may be artificially increased by cutting them in pieces, for each piece will develop into a full-sized sponge; and the absence of individuality is so marked among sponges, that whenever two or more happen to come together they soon fuse into one so completely that they leave no trace of their separate origin.

Sponges also give rise to buds, which are set free and eventually start new colonies. Germs or eggs are also formed towards the end of the summer, and develop early in the following year.

The River Sponge is common in the Thames and many other British rivers, and may be found in enormous quantities attached to the timberwork of locks and other structures both in rivers and canals. It is anything but pretty—until we examine it with the microscope; and no one unacquainted with it would suppose that the dirty greenish or yellowish slime was a colony of living beings.

But even though the animal is very unsightly, and, withal, often discharges gases of a very unpleasant odour when disturbed, yet I strongly recommend any one who possesses a microscope to take home a small supply for examination as well as for general observation in the aquarium.

The Pond Sponge is very similar in character, but is of a dark green colour, and is generally found in rounded or oval masses.

The spicules of both species may be easily obtained for microscopic examination. If you allow a vessel containing a freshwater sponge to remain exposed to air till the animal is dead and quite decomposed, then the silicious spicules may be found among the sediment at the bottom. Pour off the liquid, leaving the sediment behind, and then fill up the vessel with fresh water. After allowing a short time for the little heavy spicules to sink to the bottom, pour off the water again, together with the lighter floating matter which still remains suspended. Repeat this a few times, and the spicules will have been freed from a large proportion of the miscellaneous sediment.

Nitric acid (aqua fortis) may then be poured on the remainder. This will destroy all the organic matter of the residue, as well as limy and other substances, but will not attack the silicious spicules, which will now form almost the entire sediment.

There will be no need to await the slow natural decomposition of a sponge if the spicules are desired within a short time, for the living sponge may be treated at once with aqua fortis, and the necessary sediment obtained after no more time than is necessary to perform a few careful washings.

We now pass on to a third sub-kingdom—the *Cœlenterata*—which includes all sea anemones and corals. Nearly all the *Cœlenterates* are marine animals, but they are represented in our ponds by the *Hydra* or Freshwater Polype, of which there are two species, one commonly known as the Green Hydra (*Hydra viridis*) and the other as the Brown Hydra (*H. fusca*).

These two species are so much alike, except in the matter of colour, that the same description will answer for both; and they are so common that no one need remain ignorant of their structure and habits. Also, since the Hydra reaches a length of from a quarter to half an inch, its interesting ways can be studied to some extent with no further aid than an ordinary hand lens.

When Hydras are required, a visit should be paid to a few ponds or pools, no matter how small, where the surface of the water is covered with duckweed. The only collecting apparatus necessary is a few small bottles of about one ounce capacity and fitted with good corks.

It would be well to number the bottles used and to make a note of the particular pond or pool from which each is filled, such information being useful to guide one's operations on a future occasion.

The bottles should be filled at the surface in such a manner as to cause a quantity of the duckweed to flow in with the water, and may then be corked tightly and put into the pocket, for the exclusion of air during a few hours will in no way affect the living beings present.

On reaching home, the contents of each bottle should be poured into a tumbler or other convenient glass vessel, which should then be filled up with clean water and placed on a shelf close to a window that is not at the time receiving the direct rays of the sun.

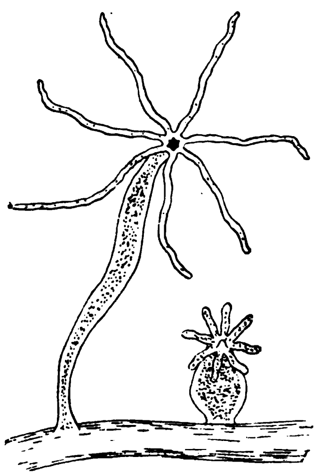


FIG. 95.—THE HYDRA, MAGNIFIED

After the glasses have remained undisturbed for some time, each one may be examined separately for Hydras. Turn the glass till the side which previously faced the window is now towards you, and then if Hydra is present it will be seen attached to the glass or the under surface of the duckweed.

Its body is long, slender, and transparent, and at the summit there are several threadlike *tentacles*, usually about six or eight in number, spreading out in all directions.

If either the tentacles or the body be touched, the former quickly disappear within the latter, and the whole body shrinks up into a rounded mass. But soon the creature slowly extends itself again, and its tentacles may be seen gently swaying about in the water.

At the top of the body, in the middle of the crown from which the tentacles radiate, is situated the mouth, on the summit of a little conical projection; and this communicates with a cavity within the body that serves the purpose of a stomach.

Should any small creature happen to strike against the tentacle of a Hydra it is immediately seized and paralysed, so that escape becomes hopeless. It is then drawn towards the mouth, all the tentacles closing upon it, and finally lodged within the body cavity.

Here it is digested by the action of the fluids in the cavity, and the nutritious portion is absorbed into the system, while the indigestible matter is cast out by means of the mouth.

At first the Hydra seems to have no means of locomotion, for it remains fixed by the slightly widened base of its body for a long time together. But we shall see it travel if we only wait its own time. Sometimes it will simply detach itself from its position, and then allow its body to float away wherever the movements of the water carry it until a more suitable locality is reached, and then it will attach itself again in the same way as before.

At other times it will hold on by means of its tentacles and bring the hinder extremity of its body close to its 'head,' thus drawing itself up into a loop. Then it will extend itself forward and repeat the process, making headway by a series of strides much after the manner of a 'geometer' caterpillar.

It is of no use to irritate the Hydra in order to compel it to move, for, as we have already observed, this treatment simply causes it to contract itself into a ball. The simplest way is to turn it from the light, and sooner or later it will make for the other side of the glass.

If Hydras are to be set aside for future observations, it will be necessary to see that they are provided with food; and the simplest way to accomplish this is to supply them with some pond water in which small creatures such as cyclops (p. 194) and water fleas (p. 193) abound. This will enable you to watch not only the hydra's method of capturing and disposing of its prey, but also to observe at least one of its means of reproducing its kind.

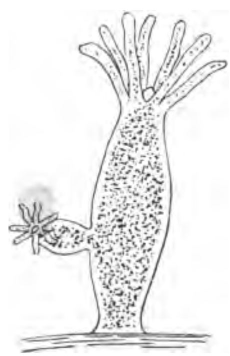


Fig. 96.—The Hydra with developing Bud

At times you may notice one or more small globular or pear-shaped prominences growing out of the side of its body. These are buds which will soon develop into new individuals. Each one will gradually elongate, and then give rise to tentacles like those of its parent; and finally it will become detached and start an independent existence. And not infrequently do we see other buds developing on the bodies of the young Hydras before they are fully formed, so that there are three generations all joined into one living mass!

This is not the only means by which the Hydra is capable of reproducing its kind. It has been stated that when the creature is cut in two each part becomes a complete animal, and it is possible that this process of multiplication may take place naturally. And this is not all, for during the warm summer months comparatively large ovaries or egg cases may be seen near the base of the animal. Each of these contains a large cell, which eventually divides up into a number of smaller cells, and then, after developing a thick outer case, becomes an egg, which detaches itself and gives rise to a new Hydra.

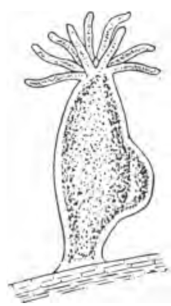


FIG. 97.—HYDRA WITH OVARY

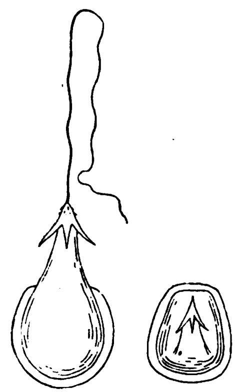


FIG. 98.—THREAD CELLS OF THE HYDRA, HIGHLY MAGNIFIED

Many of the foregoing observations may be carried on without the assistance of any great magnifying power; but if we remove a Hydra from the water by means of a dipping tube and transfer it to the live-box of a compound microscope, many other interesting features may be observed. Thus we may see that the body wall consists of two distinct layers of cells, that the walls of the tentacles are a continuation of the body wall, and that the tentacles are tubular throughout their length, and are really extensions of the general body cavity.

Some of the outer cells of the tentacles are pear-shaped, and barbed at the narrow end. Within them there is also a coiled thread. These are called 'thread cells,' and it is by means of these that the creature is enabled to paralyse its prey. The coiled threads are capable of being thrust out very suddenly, so that they assist in entangling the struggling victim, and probably also sting or stupefy it. Similar cells are also found in the outer layer of the body, but are not nearly so numerous as in the organs of prehension.

After what has been said, it will be seen that the Hydra is really a very simply formed creature. It has no complicated digestive apparatus, the general body cavity performing all the functions of alimentation. Neither has it any special organ of respiration, but receives the oxygen it requires direct from the water in which it lives, the same being absorbed through its soft gelatinous body. It has also no organs of excretion to carry off the waste from its tissues, and it possesses no nervous system, though it has 'nerve cells' by which it becomes cognisant of the world around it.

CHAPTER VII

WORMS, LEECHES, AND THEIR ALLIES

We have now to pass over an extensive sub-kingdom (*Echinodermata*) of marine animals, including the well-known Starfishes and Sea Urchins, in order to study the worms, leeches, and other allied creatures that inhabit our ponds and streams.

Before entering into details concerning individual species, I shall note the principal characteristics of the sub-kingdom (*Vermes*) to which they belong; and I strongly advise the reader to compare my description as far as he can with his own observations on one of the larger British members of the group, such as the common Horse Leech or the Earthworm. He may not have the knowledge and skill necessary to make an effectual study of the internal anatomy of the specimen selected, but much may be learnt by means of an examination of the exterior and a simple dissection.

For the latter purpose the dead animal should be pinned to a sheet of weighted cork, and opened under water by means of a very sharp knife or a fine-pointed pair of scissors. Such an examination will at least show that the creatures of this sub-kingdom are far more highly organised than those which we have previously observed, even though some of them are so small as to require the assistance of a microscope for detailed observation.

The *Vermes* are soft-bodied animals, and are generally long and narrow. In many cases, as in earthworms and leeches, the body consists of a number of segments, the divisions between which are often visible from the outside as well as within.

The digestive tube generally runs throughout the entire length of the body, and often contains a crop and a masticating gizzard.

Worms have no true heart, but they often possess a well-developed system of blood-vessels, including some which are dilated and contractile, and are thus capable of performing a function similar to that of the heart of higher animals, though less complicated in character. The blood itself is sometimes coloured, but the colour belongs to the fluid, and is not that of little floating corpuscles such as exist in the blood of most of the vertebrate animals.

A nervous system is present in all but the lowest division of this sub-kingdom, and it is often well developed, consisting of a few ganglia or masses of nerve substance forming a ring round the food passage near the mouth, and representing the brain of vertebrate animals, and also of a single or double nerve cord extending backwards from these ganglia throughout the length of the body. These nerve cords have swellings in each of the segments, and from them nerves branch off right and left.

The lowest animals of this sub-kingdom are the *Turbellarians*—a class of small flattened creatures that crawl about like slugs, or swim by the aid of the cilia that fringe their bodies. Many of these are marine, but there are several species to be found in ponds and ditches, and some inhabit moist ground and mosses.

Some are so small that they might be mistaken for infusoria when swimming by means of their cilia; but the microscope shows that they are much more highly developed than the Protozoa. They have a system of water-vessels, opening externally by little pores; and the digestive canal is often disposed in such a manner as to resemble a number of branches and twigs all radiating from a central trunk. A double nerve ganglion is also visible near the anterior end, as well as several nerves that radiate from it.

The largest of our freshwater *Turbellarians* are considerably less than an inch in length, and they are generally so imperfectly known that we are compelled to leave them with only a passing notice.

In small and putrid pools, especially where rapid decomposition of organic matter is in progress, we often find little threadlike creatures called *Nematoids* or, more commonly, Threadworms. They are also to be met with in exposed mud, among decaying vegetation on land, and in the rotting wood of hollow trees.

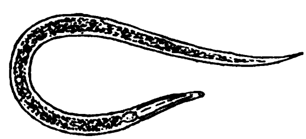


FIG. 99.—A *Nematoid*

Most of the species of this group (*Nematoidea*) are parasitic, and more than one infest human beings; but some, which are spoken of as the 'free *Nematoids*,' subsist entirely on decomposing matter.

There are few who have not seen the 'eels' that are so often met with in vinegar, and the little creatures known by the same popular name that find their way into sour paste. These are typical examples of the free *Nematoids*, and will serve to give a general idea of the group.

Some of our freshwater species are only a hundredth of an inch in length, and the largest measure only about five-eighths of an inch. They shelter themselves in mud, or hide among the vegetation of various aquatic and semi-aquatic plants. Many are very sluggish, and seldom attempt to swim unless disturbed; but others are almost incessantly wriggling their bodies in an undulatory fashion, something like that of the true eels.

It is an interesting fact that many of the *Nematoids* are capable of developing only to a limited extent in freshwater pools and streams, but that if they are taken into the digestive tube of a higher animal they reach maturity within the body of their host, feeding on its tissues, and finally laying their eggs within its body.

As a rule, however, such parasites never reach a stage that may be termed wormlike until they enter their host's body; still it is possible that many of the so-called '*free Nematoids*' that attain the wormlike stage in water or mud are really parasitic when the favourable opportunity presents itself.

It may be mentioned too, in passing, that some *Nematoids* have the remarkable power of existing for a long time in a dry condition; and even after having been dried to a dust with the aid of chemical desiccators, they rapidly regain their vitality when moistened.

This feature will account for the unexpected appearance of worms in vinegar, paste, and other fermenting substances in our houses, they having developed from particles of living though dormant dust which have been carried with the breeze.

Rotifers

Among the most interesting of the allies of worms are the little creatures known as *Rotifers*, *Rotatoria*, or Wheel Animalcules, which abound in stagnant water and sluggish streams.

The young student of natural history may not see why creatures so small and so unlike the familiar earthworm should be placed in the same sub-kingdom of the animal world; but it must be remembered that naturalists are guided in their methods of classification by features other than the mere external likeness of adult forms of life, and the true relationship existing between different animals is sometimes made manifest only after carefully tracing their development from the very earliest to the mature stage.

If we thus trace the higher aquatic worms through their juvenile days, we find that the young creatures are not at all like their parents in general form and habits, but that they are active little animals that swim freely in the water by means of minute vibratile cilia, arranged in little circles round the edges of lobes or discs, and therefore undergo remarkable metamorphoses before they assume the form of the adult. These early stages to which we refer are often spoken of as the larvæ, just as are the grubs and caterpillars which ultimately develop into perfect insects.

Now the Rotifers very closely resemble the larvæ of these higher worms. They are, as it were, worms which arrive at maturity and become capable of reproducing their kind without the necessity of metamorphoses, and without ever reaching the development attained by their higher relatives. It must be observed, too, that the Rotifers do not exhibit segmentation like the higher adult worms.

Some of the Rotifers are so large as to be distinctly visible to the naked eye, but in all cases the microscope is necessary to make out the details of their structure; and their bodies are so transparent that the whole of their internal anatomy is readily displayed by transmitted light.

The lobes or discs which bear the cilia are very prominent, and the little hairlike projections vibrate in such a manner as to give the appearance of revolving wheels—a feature which will account for the names by which they are known.

The largest species measure about a tenth of an inch in length, while some are so small that five hundred placed in a line end to end would only extend one inch. Some remain fixed to weeds and other submerged objects by the flattened bases of their bodies, like the Hydra; others attach themselves at intervals of rest by forceplike appendages at the 'tail'; the remainder are free swimmers.

It is interesting to observe that the female Rotifers are much more abundant than the males; and that while the latter have no digestive tube, the former have a complicated digestive apparatus, often including a powerful gizzard in which the food is crushed by the action of hard structures on each other.

Like the Nematoids, Rotifers are capable of retaining life after having been thoroughly dried, and are thus capable of being blown about, and of resuming activity whenever they come in contact with moisture.

Our first example is perhaps the commonest of all the Rotifers. Its body is almost cylindrical, but tapering behind, and the head and tail are both retractile. The head is furnished with two ciliated discs, which give the appearance of revolving wheels when the little processes are at work.

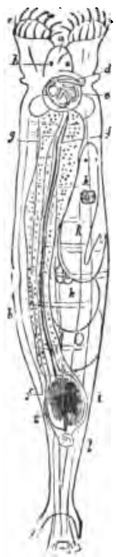


FIG. 100.—*Rotifer vulgaris*

a, mouth; b, eyes; c, cilia; d, gizzard; f, food canal; k, developing embryos; l anus

Let us place a little water containing this Rotifer in the live-box, so that we may watch its movements. It has apparently resented our disturbance, for it has retracted its tail and ciliated discs, and assumed an almost globular form.

This period of rest is not prolonged, however, for the body soon elongates slowly, the telescopic tail is protruded, the discs are also exposed, and the vibration of the two circles of cilia is rapidly progressing.

Yet the little creature is undoubtedly dissatisfied with its new quarters, for it commences to crawl over the delicate confervoid threads within the box. It extends its body in the chosen direction, fixes its head, draws its body into a loop by bringing the tail forward, and then, holding on by the tail, repeats the movement, thus making progress like a looper caterpillar, as we have already observed in the case of Hydra.

Then, not being content with the slow progress thus made, it starts swimming, keeping the wheels revolving rapidly as it goes.

Finally it moors itself by its 'foot,' as the hinder extremity is sometimes called; but its condition is not now one of absolute rest. The cilia are still vibrating, producing vigorous whirlpools which bring floating particles into the creature's mouth.

While thus fixed we take the favourable opportunity of observing the creature's structure. We note the dark eye-spots just behind the lip of the mouth, and trace the food passage through the transparent body to its termination—the anus—near the tail. We mark the food particles as they pass through the digestive canal, and observe the grinding action of the gizzard, and even distinguish the young Rotifers developing within the body of the parent.

We figure a few others of this interesting class, the first of which (fig. 101) is *Floscularia cornuta* or the Horned Floscule, which may often be found among water plants. To these it remains permanently fixed by the exceedingly thin and transparent case that surrounds

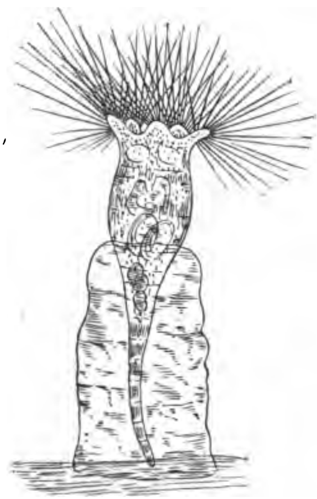


FIG. 101.—*Floscularia cornuta*

FIG. 102.—*Stephanoceros*

and encloses the lower part of its body. The case is so very delicate a structure that it is often difficult to render it visible without a proper adjustment of the light.

The summit of the body has five short lobes, and each one of these bears thirty or more very long and delicate cilia which, like the case that surrounds the body, are hardly visible. There is also a hornlike projection, but this bears no cilia.

Stephanoceros, or the Crown Animalcule, is a similar and equally beautiful Rotifer. It is almost entirely enclosed in a delicate transparent sheath, and its cilia are borne on five long radiating but retractile arms. Both this and the last species are easily visible to the naked eye, but when out of the water the natural form is entirely lost. When searching for them in the field fragments of weed should be examined in bottles of water while being held up to the light.

Some Rotifers build tubes for the protection of their soft and delicate bodies. One of the most remarkable of these is *Melicerta*, which makes its tube of reddish pellets, formed within its body of particles extracted from the water. This is also a fixed Rotifer, and

FIG. 103.—*Melicerta*

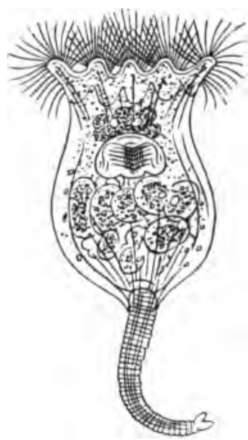


FIG. 104.—*Brachionus urceolaris*

FIG. 105.—*Dinocharis pocillum*

has marked gregarious tendencies, large numbers being met with on a single small leaf or patch of stem, their conical cases standing out at right angles from the surface.

The whole body can be retracted within the tube, which is about one twenty-fifth of an inch in length; but when the animal is disporting itself we observe four rounded lobes, two larger and two smaller, the edges of which are fringed with minute cilia.

I conclude this short outline of the Rotifers by naming and figuring two of the free-swimming kinds. These are the Pitcher Rotifer (*Brachionus urceolaris*), with one eye and a forked foot; and the Skeleton Rotifer (*Dinocharis pocillum*).

The enthusiastic pond-hunter will meet with other species not described; but the foregoing remarks will suffice to give the reader the general features of this interesting class, and to put him in a position to commence his own observations and investigations of the remarkable variety of form and habit which these creatures exhibit.

Leeches (Hirudinea)

In almost every standing pond and sluggish stream we shall meet with leeches, one species of which—the common Horse Leech—is familiar to nearly all who take the slightest interest in the varied forms of animal life.

When remarking on the general characters of Rotifers it was found necessary to give reasons for placing these little creatures in the same sub-kingdom as the worms, but no such precaution is necessary in the present instance, for leeches are decidedly worm-like in general appearance. Their bodies are soft and elongated, and, like those of earthworms, composed of a large number of segments which are often distinctly marked from without; and where the segmentation is not apparent on the surface the divisions are always clearly marked within.

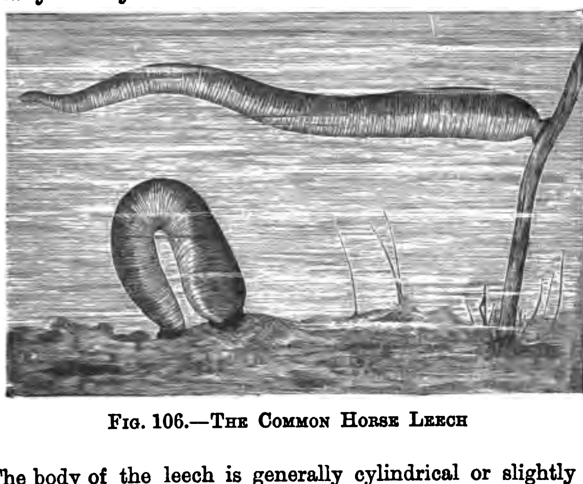


FIG. 106.—THE COMMON HORSE LEECH

The body of the leech is generally cylindrical or slightly flattened, and tapering more or less both before and behind. At the foremost extremity there is a circular sucking disc, by means of which the animal can hold on firmly to solid objects, and the mouth is generally situated in this disc. Some leeches have also a sucking disc at the posterior extremity, and these are thus enabled to progress somewhat rapidly by alternately looping and extending their bodies, again reminding us of the familiar movements of the looper caterpillar.

Fig. 107.—Digestive Tube of Leech

The most effectual means of locomotion, however, is swimming. The leech loosens its hold, and immediately flattens its body by the contraction of muscles which connect the upper and lower integument, so that it assumes a flat and ribbon-like form. Then it executes a very graceful undulatory movement, thus propelling itself rapidly through the water.

Some leeches derive their food by suction from the bodies of vertebrate and other animals, and these are provided with horny, toothed jaws by which they can inflict a wound of sufficient depth to allow the blood to be drawn.

The digestive canal runs straight through the body, and gives oft a number of pouchlike extensions on each side.

The nervous system is composed of a number of ganglia, forming, with their connecting nerves, a continuous double chain. The

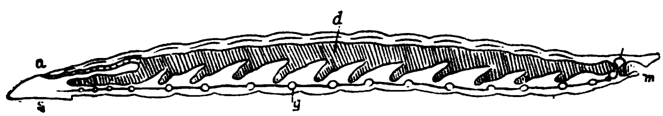


Fig. 108.—Section of Leech, showing Digestive and Nervous Systems

m, mouth; *d*, digestive tube; *a*, anus; *s*, anal sucker; *g*, nerve ganglion

first pair of ganglia are much larger than the others, and represent the brain in higher animals. The others are all arranged in pairs—one pair in each segment, close to the lower surface of the body.

Even those leeches which live by sucking the blood of other animals have blood-vessels of their own, for the fluid they imbibe is not in quite a fit condition to directly nourish their own bodies, but has to be digested before it can build up their tissues. Thus the leeches require a system of vessels to collect up the digested matter, and to convey it in the form of the creatures' own blood for the nourishment of their tissues.

In each segment of the body of a leech there is an organ called the *segmental organ.* These organs are really a series of water-vessels, each of which opens by means of a tube at the side of its segment.

The two leeches most generally known in this country are the Horse Leech and the Medicinal Leech. The latter seems to have been taken somewhat extensively from our own waters, particularly in the south, but it is now seldom seen except in captivity, and these captive leeches have been imported from the Continent, principally from Austria and Sardinia. It is also very probable that

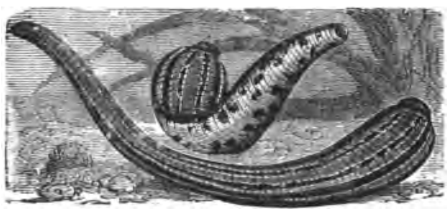


FIG. 109.—THE MEDICINAL LEECH

specimens of this leech taken in our own ponds are sometimes escaped foreigners which have been imported for medicinal purposes. I have now two alive in an aquarium, that were taken from the same pond on a common near London. Although I have diligently searched this pond several times since the capture was made, I have never taken another of the same species.

The Medicinal Leech (*Hirudo medicinalis*) is about three inches long, but capable of extension to six or seven inches. It is of a greenish colour, and may be readily known by the six interrupted yellow bands which run longitudinally along its upper surface.

The Horse Leech is of about the same size, coloured with a very dark olive-green above and a lighter yellowish-green below. It does not prey on vertebrate animals, except that it occasionally attacks the frog, but derives its food by suction from such animals as worms, soft-bodied larvæ, and even its own kind. Its teeth are small, and it has no power to inflict a wound except in the case of soft-bodied creatures.

We have several other leeches, some very small and apparently but little known; and others so transparent that all their internal organs can be readily seen as they crawl about the sides of a glass aquarium. Such observations, however, are sufficient to try one's patience, for these organs are best displayed only when the body of the creature is fully extended at each stride, and it is rather tiresome to have to follow it with a magnifier to make out the details of its structure while it is apparently trying to cover as much ground as possible in a given time.

Bryozoa

The *Bryozoa* or Moss Polypes are extremely abundant on all our shores, but rather sparingly represented in fresh water.

The animals of this class were once grouped with the lowly organised *Hydrozoa* or Jelly Fishes, to which they certainly bear an external resemblance; but it is now pretty generally agreed that their relationships are rather with the worms.

Like many of the marine *Hydrozoa*, they live in colonies, all the members of the same colony being joined together by a common base, and hence they are frequently spoken of as the *Polyzoa.*

Each little polyp is surrounded by a membranous sac, at the summit of which is the mouth, surrounded by several long, ciliated, hollow tentacles, which, in our freshwater species, are generally arranged on a U-shaped base.

Unlike the *Hydrozoa*, they have a fairly well-developed digestive tube, consisting of an œsophagus, an enlargement which serves the purpose of a stomach, and an intestine terminating in a vent or *anus.*

This tube is bent on itself in such a manner that the anus is very near the mouth, and a nerve ganglion is situated on one side of it, within the bend.

The first portion of the digestive tube, together with the tentacles, can be protracted or retracted at will, and thus the general appearance of the polype is made to vary very considerably at different times.

One of the best known of our freshwater *Bryozoa* is *Plumatella repens*—the commonest of its genus, which contains several species.

The whole colony is a branching structure, not very compact, but spreading on the under surfaces of floating weeds and of submerged objects in very shallow water, much after the manner of the stems of certain creeping plants.

Small apertures are visible at short intervals in this branching structure, and, when quite undisturbed, the beautiful plumelike

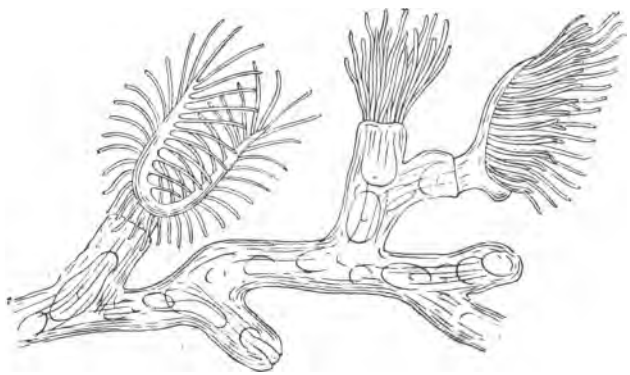


FIG. 110.—*Plumatella repens*—PORTION OF A COLONY

cluster of tentacles, sixty in number in each individual, may be seen extended. But on the slightest disturbance the plumes are quickly retracted, so that the chief beauty of the colony disappears.

Another species (*Lophopus*) is very different in general appearance, for here the colony consists of only about a dozen individuals, and these do not spread and branch, but all display themselves from within an inverted oval gelatinous cup.

The longest diameter of the colony is often quite half an inch in length; but, although so large, no one unacquainted with the *Bryozoa* would imagine for a moment that the shapeless mass of jelly he observes on the under side of a floating leaf was a cluster of such beautiful creatures.

Place the object in the live-box, however, and let it remain at perfect rest for a time; and then the once shapeless mass assumes the form of a delicate cup, and one by one the polypes extend themselves from their cylindrical sacs and display their beautiful plumes.

Both this and the last named should be looked for towards the end of summer, and even up to the time of late autumn. They are exceedingly pretty objects for the microscope, and display, in addition to their plumes, the whole of their internal anatomy, for the substance of their body is clear and transparent.

The reader is recommended to always find a place in his collecting bottle for any leaves or stems that are found to be covered with patches of transparent and shapeless jelly, or with a whitish downy-looking or slimy substance. Such patches should always be examined with a lens after the bottle has been at rest for a time, and in this way he will probably make himself practically acquainted with some of the most beautiful forms of aquatic life, the microscopic examination of which will well repay him.

It must be mentioned, in conclusion, that although most of our *Bryozoa* remain fixed to one object, we have one, called *Cristatella*, that moves freely at times—not the single individuals, but the whole colony forming one moving mass. It is oval in form, flat on one side and convex on the other, and usually half an inch or more in length.

It sometimes remains quite stationary on the surface of a submerged leaf or stem, using its flattened side as an adhesive disc or foot; but when undisturbed it may be seen slowly creeping about, displaying a number of clusters of tentacles all round the margin of the colony.

CHAPTER VIII

FRESHWATER MOLLUSCS

A VERY brief outline of the more important distinguishing characteristics of the sub-kingdom *Mollusca* was given in the first chapter, in which it was also stated that the group is divided by naturalists into three classes.

Two of these classes are very well represented in our ponds and streams; and in order to make ourselves familiar with the general structure of the two divisions, we shall select a typical representative from each, and examine it with the aid of simple dissections.

The first example shall be the Freshwater Mussel (*Anodonta*)—a type of the lowest class of the mollusca. The members of this class have no distinct head, and are therefore often spoken of as the Headless Molluscs (*Acephala*). They are now more generally termed the *Lamellibranchs*, and the class which they form the *Lamellibranchiata*. These names signify 'plate-gilled,' and are applied on account of the fact that the gills by which the animals breathe are composed of thin membranous plates. They are also called *Bivalves*, their outer shelly covering consisting of two 'valves' that move one on the other in a manner to be presently described.

The student of pond life should procure one or two freshwater mussels, and after a careful observation of their habits in the aquarium, proceed to look into the details of their structure as far as his ability permits.

Place the live animals in an aquarium, on a layer of fine sand. For a time they will remain perfectly motionless, with their shells tightly closed; but if left undisturbed, they will at last slowly open the two shells, and thrust out from between them a conical mass of flesh which is called the 'foot.' After a number of sluggish movements they will succeed in completely burying the foot and placing their shells on edge in an oblique position, with a portion of the valves concealed beneath the surface of the sand.

The narrower or posterior end of the shell will now be seen to gape a little, and two openings will be visible here in a membrane which protrudes slightly beyond the margin. These openings are called siphons, and are the means by which currents of water enter and leave the body.

If now a solution of some harmless soluble colouring matter, such

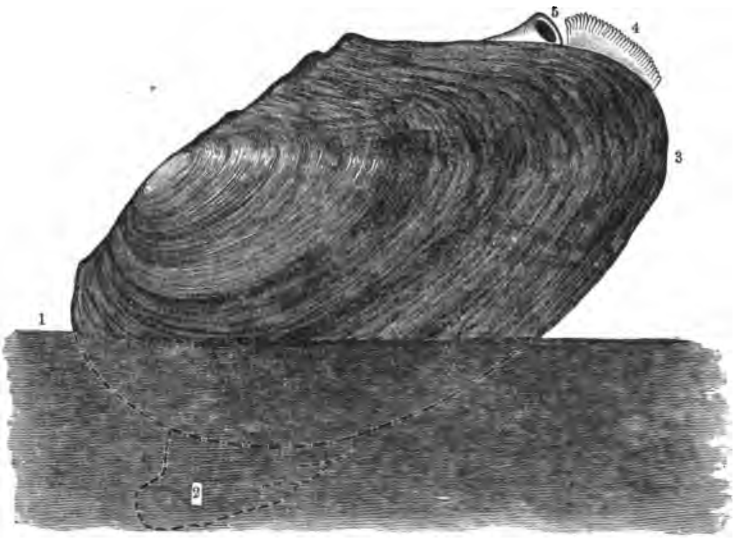


FIG. 111.—THE FRESHWATER MUSSEL (*Anodonta cygnea*) AS SEEN IN THE AQUARIUM

1, anterior end of shell; 2, foot; 3, posterior end of shell; 4, inhaling siphon; 5, exhaling siphon

as cochineal, be passed gently to the neighbourhood of these channels through a fine glass tube, it will at once reveal two well-defined currents of water, one passing into the body cavity of the mussel through the larger and more posterior tube—the *inhalent siphon*—and the other ejected through the *exhalent* siphon. The inhalent siphon is surrounded by a number of little projections called *tentacles*. These all project inwards, thus forming a kind of strainer to prevent the entrance of large particles. It will be observed, too, that the Anodonta does not remain fixed in one spot, but that it has a decided power of locomotion; and although its movements are even slower than those of the proverbial tortoise, yet in time it will cover a deal of ground, leaving its 'tracks' in the form of shallow grooves in the mud or sand that supports it.

There is some difficulty in keeping the Anodonta alive for a long time in a small indoor aquarium, and this is due chiefly to the nature of its food. It subsists entirely on microscopic animals and plants (chiefly *infusoria* and *diatoms*) that are carried into its system through the inhalent siphon, and no ordinary indoor aquarium can be expected to supply these in such quantities as to support this large bivalve. Frequent changes of water, or even running water, if from the household supply, will not improve the condition, as, fortunately, our drinking-water is not usually rich in low forms of life. I have found the Anodonta thrive best in still water, without change of any kind, either in a large glass aquarium or the garden pond, with plenty of aquatic vegetation and a good light; for it is under these circumstances that we may expect a rapid succession of microscopic beings such as the creature requires.

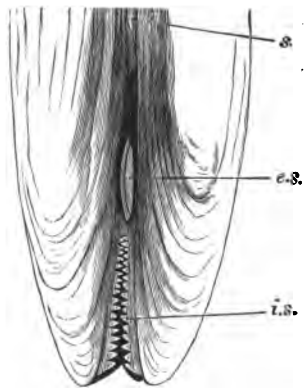


FIG. 112.—POSTERIOR END OF SHELL OF *Anodonta*, SHOWING THE INHALENT SIPHON WITH ITS TENTACLES (*i.s.*), AND THE EXHALENT SIPHON (*e.s.*)

Now let us see what is to be learnt by a closer examination of this *lamellibranch*. First we will inspect the exterior of the shell, the animal alive or dead—it matters not which.

It will be observed that the two valves are united on what is termed the *dorsal border* by means of a very strong substance—the *ligament*, which projects a little beyond the margin, close to the *hinge*, or junction where the valves form a moveable joint. Both valves are convex without, each forming a sort of very depressed cone, the apex of which, called the *umbone*, projects a little beyond the dorsal edge.

The shell increases in thickness, as the animal grows, by additions on the interior, and in area by the formation of new layers at the edge. Hence the umbone represents the first shell of the young mollusc, and the concentric curved lines which are so distinctly visible on the outside mark the margins of the shell at different stages of growth. Thus we speak of these lines as the lines of growth.

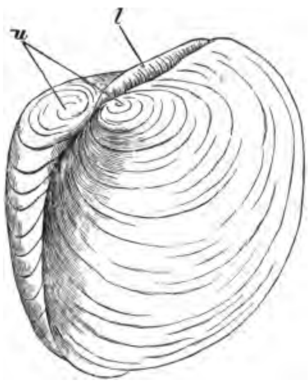


FIG. 113.—SHELL OF *Anodonta cygnea*, SHOWING THE *ligament* (*l*) AND THE *umbones* (*u*)

For the further examination of the shell we must look inside; and if an empty specimen is not ready at hand, the animal must be killed for the purpose.

This may be done by immersion in boiling water—the quickest and most merciful method of killing a mollusc without injury to the shell.

As soon as the animal is dead, the valves gape considerably, being pulled open by the elasticity of the ligament, which during life is always maintained 'on the stretch' by the contraction of two strong muscular pillars passing from one valve to another.

These muscles are called the *adductors*; and as the shell gapes it will be seen that one is situated near the broader or anterior end of the shell, and the other near the posterior end.

Pass a sharp knife between the valves, and cut through the adductors close to the shell. The elastic ligament is now quite unopposed, and the shell gapes more than before. Next remove the animal completely from its calcareous house, and examine the interior.

The hinge now appears as a ridge running along a portion of the dorsal margin of each valve. This is the simplest kind of hinge observable in the shells of molluscs. In some species this joint is a far more complicated and even a beautiful structure; and, since the nature of the hinge is often a very valuable assistance in the identification of bivalves, it will be well to depart for a moment from the examination of our *Anodonta* in order to become acquainted with the parts of a more perfect hinge and the terms by which these parts are known and described.

There are often interlocking projections of various forms on differenc portions of the hinge. These are called *teeth*, and are named according to their position with regard to the umbone of the valve on which they are situated. Those situated immediately below the umbone are called *cardinal teeth*. Those in front of the umbone—that is, on the side towards the anterior end of the valve—are termed the *anterior teeth*, and those on the other side of the umbone the *posterior teeth*.

Again, as the disposition of the teeth is not exactly the same on both valves of the same species, it is absolutely necessary that, for purposes of description, each valve shall have its name. To this

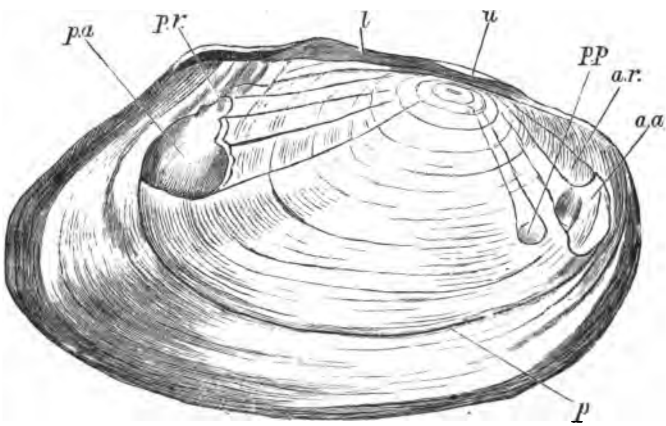


FIG. 114.—INTERIOR SURFACE OF THE LEFT VALVE OF *Anodonta cygnea*

p, pallial line; *p.a*, impression of the posterior adductor muscle; *p.r*, impression of posterior retractor; *a.a*, of anterior adductor; *a.r*, of anterior retractor; *p.p*, of the protractor pedis muscle; *u*, umbo; *l*, ligament

end they are termed respectively *right* and *left*, and are to be distinguished from each other in this manner: Hold the closed shell on its edge with the hinge uppermost and the narrow posterior end towards you, and you have then the right and left valves turned towards *your* right and left respectively.

Now to return to our Anodonta. When removing the animal from its shell, we observe that the outer surface of the body is attached to each valve along a line (*pallial line*) which runs almost parallel with the lower or *ventral* margin, and extends throughout the whole length of the shell; and after the soft structures have all been removed, this line is distinctly visible on the inner pearly surface of the valves, as are also the concentric lines of growth previously mentioned as marking the exterior.

The interior surface of the shell is further marked by the impressions of the various muscles that serve to move the valves and the foot.

Near the posterior end, and bordered behind by the pallial line, is the large scar that marks the attachment of the *posterior adductor muscle*, which closes the valves by its contraction; and immediately above it is the smaller impression of the *posterior retractor*, which draws in the foot.

At the anterior end may be seen the impressions of the *anterior adductor muscle*, which aids the corresponding posterior muscle in closing the valves; also of the *anterior retractor*, which withdraws the foot, and the *protractor pedis*, which assists in extending the foot.

It is further interesting to note that all these muscular impressions have faintly marked lines extending from their circumferences towards the umbo, converging as they proceed. These lines enable us to trace the various positions previously occupied by the respective muscles as they advanced with the gradual growth of the shell.

Before closing the inspection of the shell we will cut a small furrow from the umbo to the ventral surface of one of the valves with a small triangular file, and then break it across. If now we smooth over the broken edge, and examine it with a magnifying lens, we shall see that it is composed of three distinct layers. Outside is a very thin horny layer, of a brownish colour, which covers the entire outer surface and, bending round the ventral edge, extends a little way over the inner surface. Next to this is a layer composed of prisms or pillars of carbonate of lime, standing out at right angles to the surface. Lastly, we observe the inner pearly layer, composed of thin layers of matter, some of which are calcareous and some not, arranged alternately.

We have now to examine the soft structures of the animal itself. For this purpose we shall find it advantageous to kill one of our mussels either in a solution of mercuric chloride (corrosive sublimate), or by putting it into cold water, and heating gradually until the valves open.

When the animal is treated in either of these ways, the form of the body is not so much distorted nor the organs pushed so much out of their natural positions by violent contractions of the muscles of the foot as when killed by some other means.

Now insert a sharp knife between the valves, and cut through the muscles on one side close to the surface of the shell; and then cut through the ligament, and remove the upper valve, leaving the animal attached by its muscles to the lower one. If this operation be skilfully performed, nothing will be in the least damaged, with the exception of the muscles above mentioned.

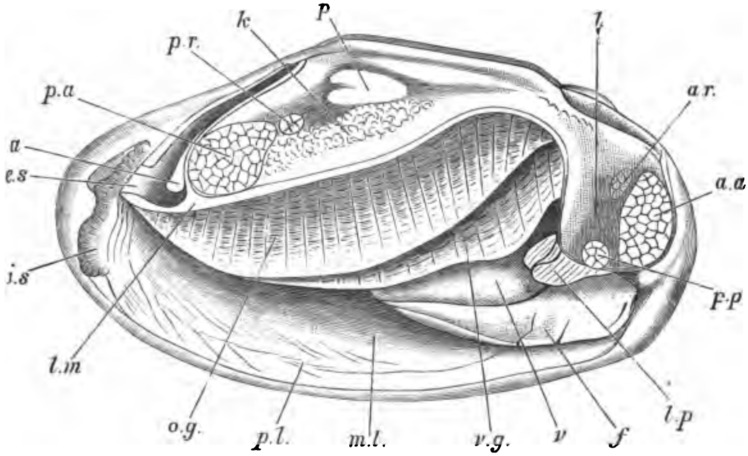


FIG. 115.—*Anodonta*, LYING IN ONE VALVE, WITH UPPER LOBE OF THE MANTLE REMOVED

p, pericardium; *k*, kidney; *p.r*, posterior retractor muscle; *p.a*, posterior adductor muscle; *a.a*, anterior adductor muscle; *a.r*, anterior retractor muscle; *p.p*, protractor pedis muscle; *a*, anus; *e.s*, exhalent siphon; *i.s*, inhalent siphon; *l.m*, cut edge of the mantle; *o.g*, outer gill-plate; *m.l*, mantle lobe; *v.g*, inner gill-plate; *v*, internal organs; *f*, foot; *l.p*, labial palps; *l*, liver

Lay the animal in a shallow dish or trough, with just sufficient clean water to cover it, and then proceed to observe its structure.

The first thing that strikes the attention is the membrane which forms the covering of the body and lines the shell, extending nearly to its ventral edge. This is the membrane to which we have already referred as being attached to the shell along the pallial line. It is called the *mantle*, and the shell itself is formed by the secretive power of the membrane.

If the upper half of the mantle be raised, and cut off with a pair of scissors without touching any other structures, the other parts of the body will be displayed as in fig. 115.

Above are seen two large gill-plates extending throughout almost the entire length of the body, and if these are lifted two corresponding ones will be observed on the under side.

Towards the anterior end the gill-plates of either side are separated by the foot and the mass of viscera or internal organs; but behind the two inner gill-plates are united, thus enclosing a large cavity or chamber.

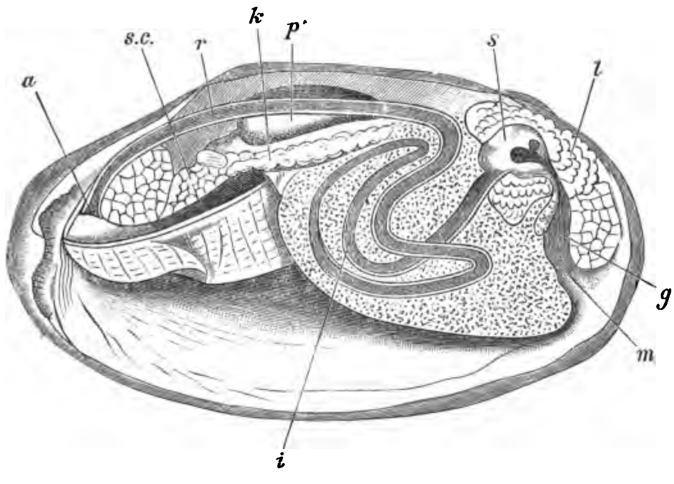


Fig. 116.—Section of *Anodonta*, showing the Digestive Tube

m, mouth; *g*, gullet; *l*, liver; *s*, stomach; *i,r*, intestine; *a*, anus; *p*, pericardium; *k*, kidney; *s.c*, chamber above the gills

In front of the gills are two pairs of triangular flaps—the *labial palps*, between which the mouth is situated.

Above the gills is the dark-coloured organ sometimes called the *kidney*; and above this again, very near the ligament of the shell, is the cavity termed the pericardium, within which may be seen the heart.

Further, in front of the gills—that is, at the anterior end of these organs—is the dark brown digestive gland, often called the liver:

and within this lies the stomach, which communicates with the mouth by means of the short *gullet* or *œsophagus*.

Other structures may be revealed by means of simple but careful dissections, conducted with the aid of a sharp knife, a pair of forceps, and a pair of pointed scissors. Thus the three-chambered heart, consisting of a thick-walled ventricle and two thin-walled auricles, and the vessels which convey the colourless blood to and from it, may be seen distinctly on opening the pericardium.

The digestive tube may also be traced throughout its length if its course be carefully followed. The gullet and stomach have already been mentioned; and from the latter passes the intestine. This tube is long and irregularly coiled within the body, passes *through* the heart, and terminates at the posterior end of the body, the extremity being termed the *anus*.

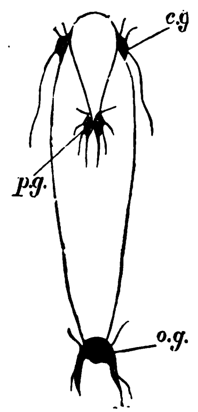


FIG. 117.—THE NERVOUS SYSTEM OF *Anodonta*

c.g, ganglia near the mouth; *p.g*, ganglia of the foot; *o.g*, ganglia of the posterior adductor

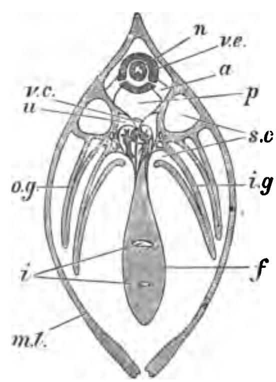


FIG. 118.—TRANSVERSE SECTION OF *Anodonta*

n, intestine; *v.e.* ventricle of the heart; *a*, auricle; *p*, pericardium; *s.c*, chamber above the gills; *v.c*, the great vein; *u*, tube communicating with the kidney; *o.g*, outer gills; *i.g*, inner gills; *i*, coils of intestine; *f*, foot; *m.l*, mantle lobe

The nervous system of *Anodonta* consists of three pairs of little masses of nerve substance (*ganglia*) connected by and giving off nerves. One pair is situated at the sides of the mouth, one pair in the foot, and the other on the posterior adductor muscle.

There is, as has already been observed, no distinct head. Nor are there any well-developed organs of sense. A sensitive membrane supplied with nerves from the last pair of the above-named ganglia is supposed to be connected with the sense of smell; and there is a pair of little sacs, supplied with nerves from the ganglia of the foot, which are regarded as auditory; but beyond these there are no known organs of special sense.

Although I cannot here enter into details of the structure and physiology of the freshwater mussel, there are one or two important and interesting features concerning the circulation and respiration that must not be overlooked; and for a better understanding of these matters it will be necessary to study for a few moments a transverse section of the animal.

Such a section is shown in fig. 118, and it gives a clear view of the relative positions of certain of the cavities and tubes, as well as of some of the solid structures.

The water which is taken into the inhalent siphon passes in part through the gills, part into the mouth, and part through a space between the gills and the body wall, and, as may be inferred, is concerned both in the respiration and in the feeding of the animal.

These streams of water are urged onward by the incessant vibration of minute hairlike projections (*cilia*) which are thickly distributed on the surface of the labial palps, the gills, and the interior of the mantle lobes; and they all find their way eventually into a cavity situated above the gills, communicating with the exhalent siphon.

That portion of the inhalent current which bathes the gills brings the necessary supply of oxygen for the aëration of the blood; the gas being held in solution by the water, and brought into such close proximity to the thickly set network of thin-walled blood capillaries of the gills, that absorption takes place very readily. At the same time, carbonic acid gas—one of the waste products of oxidation—passes from the blood into the water for removal.

The food of *Anodonta* consists of minute organisms, both animal and vegetable, chiefly infusorians and diatoms, which exist abundantly in the water in which it lives. These organisms are obtained of course from that portion of the inhalent current that enters the mouth and passes through the alimentary canal.

It will thus be seen that the water currents which flow through the system of *Anodonta* have important functions to perform; they convey the food, aërate the blood, and carry off waste products.

Finally, let us briefly trace the Anodonta through the earlier stages of its career.

During the autumn and winter the female may be found with gills swollen much beyond their normal size. If at this season we open the gills we find that the chambers between the laminæ or plates are quite full of eggs, with perhaps also a number of young that have already hatched. These are so small that two or three millions may be accommodated in the gill chambers of one single individual.

The eggs are of course not *formed* in the gills, but in organs (the ovaries) specially devoted to that function; and when the little ova or eggs are developed, they pass out through openings in those organs, and become lodged in the pouches of the gills.

When the young are hatched they bear no kind of resemblance to their parent. Indeed so different are they, that at one time they were regarded as parasites, and were named accordingly.

They certainly are bivalves, but the shells are triangular, and are joined together by an elastic hinge which extends along one side of the triangle. The opposite corners are curved inwards, and are covered with little teeth, which are arranged in such a way that they fit into one another when the two shells are brought together.

The foot is only slightly developed, and from it there arises a few long and slender filaments, forming what is called a *byssus*, and corresponding with the hairlike tuft by which the marine mussel attaches itself to the rock.

While these little creatures are lodged in the gill chambers of the parent their byssi become entangled, and so by the aid of these organs they are enabled to hold together and retain their positions.

At this stage, too, the mantle is very thin, and there is only one muscle to pull the valves together.

In the autumn or early winter the little larvæ are ejected by the parent, and then they swim about freely, the motive power being provided by the alternate opening and closing of the triangular valves.

Sooner or later each one comes in contact with a fish. It then attaches itself by means of its curved valves, and not only does it thus secure for itself a safe carrier while it undergoes its metamorphoses in a quiescent state, but the outer skin of its host actually envelops it while these changes are proceeding.

At last the metamorphoses are over. The byssus is cast away, the various internal organs have assumed the same form as those of the adult, and the triangular shells with their one adductor muscle are exchanged for new valves with two adductors.

The young mussel, now capable of looking after itself—of moving about from place to place, and of collecting its own food—allows itself to drop from the host who has unwittingly provided it with the aid it needed, and falls slowly to the mud at the bottom of the pond, where it soon fixes itself by means of its foot, and takes upon itself the habits of the adult.

The Snail

We have now to take a type of the second class of the mollusca —the *Cephalophora* or *Head-bearing Molluscs*. This class is divided into three sections: The *Scaphopoda*, with a tubular shell, open at both ends; *Pteropoda*, which swim by finlike appendages attached to the foot; and the *Gasteropoda*, which creep or swim by means of a flattened foot.

The first of these divisions includes the so-called Elephant's-tooth Shell and other marine species. The second has no representative in our ponds and streams; but the third division will occupy a considerable share of our attention.

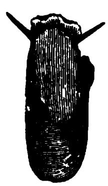


Fig. 119.—A Water Snail (*Planorbis corneus*) as seen when crawling on the glass of an aquarium

The term *Gasteropoda* signifies *belly-footed*, and the group is so named because the creatures creep or swim by means of the flattened lower surface of the body.

Some of the marine species have as many as eight valves, and these roll themselves into the form of a ball when disturbed, something after the manner of a woodlouse; but the majority of species are enclosed in one shell, and are consequently known as the *univalve molluscs*.

A good number of the univalve gasteropods have conical shells, many of which are not symmetrical. They are known popularly as the limpets. Most of the others have their shells coiled into a spiral, and are generally known as snails.

We have only two freshwater limpets, and all the other British aquatic gasteropods come under the popular heading of Snails.

It may seem strange if, in this work devoted entirely to aquatic life, we select a terrestrial snail as our type of the gasteropods. We shall do so, nevertheless, chiefly as a matter of convenience to the reader. The Common Snail (*Helix aspersa*) is so easily obtained everywhere, and is of such convenient dimensions for examination and dissection, that we can hardly do better than choose it for our present purpose.

First let us observe the general outward appearance and habits of the living animal.

The shell is conical in form, and consists of a spiral of about four *whorls* or turns. The outer whorl is much larger than the

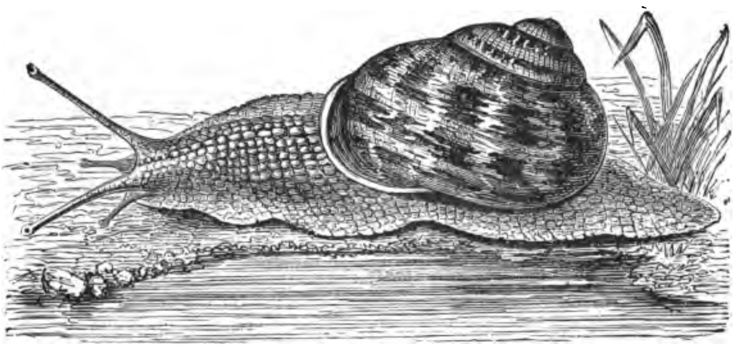


FIG. 120.—THE COMMON SNAIL (*Helix aspersa*)

others, and is therefore known as the *body whorl*; the other three form the *spire*. If you hold the shell with the apex of its spire turned towards you, and then trace a line in the direction of the whorls, from the apex to the mouth, that line will form what is termed a right-handed spiral, and consequently the shell itself is described as right-handed or *dextral*.

Some of the snails have no spire at all, the whorls being wholly or nearly so in the same plane, as in the well-known genus *Planorbis*. Again, in some, as in the genus Physa, the spiral turns to the left, and the shell is then spoken of as left-handed or *sinistral*.

The *nucleus* or apex of the cone is the oldest part of the shell, and the whorls are all marked distinctly by lines of growth running round them transversely, parallel with the rim (*peristome*) around the mouth, each one marking a former position of the aperture.

In addition to these lines, which really mark short intervals in the life history of the snail, there will be observed on the body whorl a few well-marked lines, often separating areas of different depths of colour. These each distinguish one year's growth from that of another, and are frequently so well displayed that we are enabled to form a fairly reliable estimate of the age of an old specimen.

The whorls of the shell turn round a central pillar called the *columella*; and on the under surface of some snails, close to the inner side of the peristome, may be seen an opening—the *umbilicus*, which communicates with the *cavity* of the columella.

FIG. 121.—SECTION OF THE SHELL OF A SNAIL (*Helix pomatia*), SHOWING THE HOLLOW COLUMELLA

FIG. 122.—SHELL OF *Helix aspersa*, SHOWING MOUTH AND PERISTOME

Further, it will be observed that the peristome is not *complete*. That is, it does not form a closed curve, completely surrounding the mouth, the wall on the inner side being formed by the under convex surface of the outer whorl.

When the snail is about to move, a considerable portion of its body is protruded from its shell. It will be noticed that it is much wrinkled, and covered with a soft and slimy skin. The head now becomes distinctly visible, with its two pairs of tentacles, the upper and longer of which bear the eyes. The mouth is on the under side.

The muscular mass behind the head is called the foot, and the locomotion of the animal is accomplished by a succession of wave-like contractions which travel rapidly along its flattened under surface from behind forwards. It is very interesting to observe these wavelike movements of the foot, and this may be done with the greatest ease by simply placing a snail on a piece of clean glass and then looking at the under surface of the foot through it.

If you lift the snail, and look at it from below while its foot is still extended, you will see a portion of the edge of the mantle, called the collar, and on the right side of this a rather large opening—the *pulmonary aperture*—which communicates with the breathing organ. Also, close beside it, is a smaller aperture, which is the *anus*, or outlet of the digestive tube.

Throughout the winter, and even during warm weather if the creature fails to find food, it will hibernate, drawing itself completely within its shell, the mouth of which is for the time sealed over with a film of slimė (*mucus*), which soon hardens on exposure to air. An orifice is left in this, however, for purposes of respiration.

It is very interesting to observe the snail while feeding. Provide it with a leaf of any one of our edible vegetables, and it will soon begin biting away at it in real earnest. Listen attentively and you will hear, at short intervals, a half-biting and half-rasping sound as each little semicircular piece is removed from the leaf.

Look at it from below as it eats the edge of the leaf, and the nature of its mouth and the movements of its jaws will be easily discerned. Round the mouth will be seen soft fleshy lips—one circular and surrounding the mouth, and two others, one at each side.

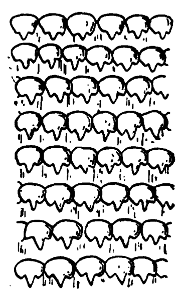


Fig. 123.—Portion of the Lingual Ribbon of the Snail, magnified

On the upper side of the mouth is the upper jaw or 'beak,' which is really a horny plate with a sharp edge below. Opposite this beak is a long and narrow slip of membrane covered with many hundreds of minute sharp projections. The membrane is often called the tongue; and the terms 'lingual ribbon' and 'odontophore' are also applied.

The teeth are so small that they cannot be seen with the unaided eye, and even with a hand lens appear only as so many delicate stripes, the stripes representing the straight rows in which the teeth are arranged. A compound microscope, however, readily shows up their real character. They are little pointed masses of silicious matter, the points being turned backwards towards the œsophagus. They are arranged in regular rows, about one hundred and thirty in all, and more than a hundred in each row, and their disposition on the 'tongue' is such as to remind one of an ordinary rasp.

The teeth are so hard that the snail has no difficulty in reducing the toughest leaf or green stalk. In fact some of the marine gasteropods even rasp through the thick shells of other molluscs and feed on the inmates.

Only the front rows of teeth are brought into opposition with the horny beak, and consequently only those are worn away. But new teeth are continually being formed on the back part of the membrane and the membrane with its teeth is always being urged forward by the new growth behind, thus bringing fresh rows of teeth to the front to replace those that are worn down.

If you touch one of the snail's tentacles while it is either feeding or creeping, the tentacle will be immediately drawn in. Watch this movement carefully with the aid of a lens, and you will see that the tentacle is pulled inside out, or rather outside in, just as you could pull the finger of a glove outside in by means of a piece of string passing through it and fastened to the inner surface at the tip.

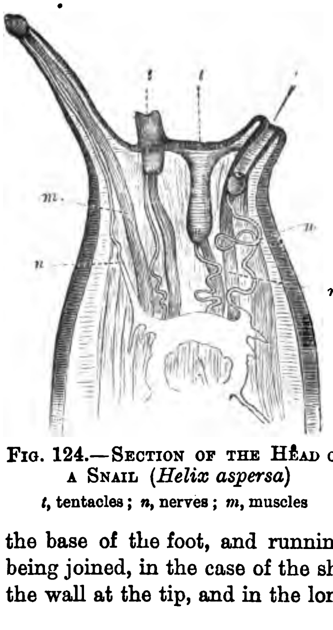


FIG. 124.—SECTION OF THE HEAD OF A SNAIL (*Helix aspersa*)
t, tentacles; *n*, nerves; *m*, muscles

This statement applies both to the longer tentacles which bear the eyes as well as to the shorter ones, and hence it will be understood that the eyes themselves will be pulled to a considerable distance within the head when the longer tentacles are retracted.

A dissection of the head of the snail shows how the movements are accomplished, for it reveals four long and narrow bands of muscular fibres passing from the muscular mass at the base of the foot, and running each into one of the tentacles, being joined, in the case of the shorter pair, to the inner surface of the wall at the tip, and in the longer pair to the base of the eye.

The wall of the tentacle itself is composed in part of muscular fibres which are arranged in circles round the tube—for it is in reality a tube; and the protrusion of the organ is brought about by the contraction of these fibres.

A careful dissection of the head will reveal other interesting structures. A large nerve ganglion will be observed at the back. This is termed the *cerebral ganglion*, since it represents the brain of vertebrate animals. From it four nerves pass forward into the tentacles, two of them being the optic nerves or nerves of vision, communicating with the eyes; and the others, belonging to the short tentacles, possibly connected with some kind of special sensation in addition to that of touch.

In order to carry out the above or any other internal examination of the snail, the animal should be killed and extracted from the shell. Perhaps the best way to accomplish the former, at least for the present purpose, is to drown the snail in cold water, or to keep it for a short time in water about twenty or thirty degrees above blood heat. Boiling water would of course be far more effectual, but it would cause an undue contraction of the muscles, and a consequent displacement of some of the internal organs. It also softens some of the organs to such an extent that it is almost impossible to examine them without their falling to pieces.

When the animal is quite dead seize the protruding portion of the body between the finger and the thumb, and then, with a twisting movement, extract the whole from the shell. During life the soft body is held to the shell by muscles which attach it to the columella, but these readily give way after a short immersion in hot water; and if about half of the shell be ground away in order to expose the columella, fragments of the white tendons which gave attachment to these muscles may be seen on the columella.

As soon as the body of the snail has been fully exposed, we observe a marked contrast between the portion that is protruded when the animal is crawling and that which remains permanently lodged within the shell during life. The former is covered with a thick wrinkled skin, while the latter is enclosed in a very thin membrane—so thin and transparent that some of the internal organs are distinctly visible beneath it.

This thin membrane is the *mantle*, which secretes the shell, and which corresponds with the bilobed membrane, of the same name, that lines the shells of lamellibranchs.

We have already mentioned the 'collar' of the snail, but its true character is more easily seen when the animal is withdrawn from its home. It is really the swollen edge of the mantle, and forms the junction between this and the outer wrinkled covering.

The shell increases in size by the addition of new layers of calcareous matter deposited on the lip, and this is always brought about through the agency of the collar. Hence when the lip of the shell is damaged it is repaired by this part. Further, the collar contains the cells which hold the colouring matter that produces the ground colour and pattern of the shell; and consequently whenever the margin of the shell is damaged the new matter added is always uniform, both in ground tint and markings, with the original part.

The thin portion of the mantle also has the power of forming shell, and by this means the shell is gradually increased in thickness by additions inside as the animal grows older. It has, however, no pigment with which to colour what it forms. Hence if a portion of either of the whorls be lost through external injury, although the missing portion is replaced, the patch of new shell formed is either white or colourless, and always remains thinner than the original shell surrounding it.

There is a difference of opinion as to the exact manner in which the shell is formed from the mantle. Some maintain that successive layers of the mantle itself are hardened by the deposition of granules of carbonate of lime, and then detached to form the shell; while others look upon the process as one of excretion, believing that layer after layer of membranous matter is thrown off by the mantle, and these are afterwards hardened by the deposit of calcareous grains which eventually almost entirely displace the softer substance.

Whichever be the case, it is easy to prove that the shell consists of membranous as well as of calcareous matter, for the former may be dissolved out by means of a hot solution of caustic potash, leaving the shell in a porous condition; or the latter may be dissolved in dilute hydrochloric acid, leaving a residue of delicate membranous tissue in which the granules of calcareous substance were deposited.

It is not necessary here to enter into the details of the structure and physiology of the snail, such details being readily attainable in numerous works on elementary biology to which the student is recommended to refer; but I shall briefly note a few of the more important points in its structure, most of which may be easily made out by simple dissections. To carry out such dissections the animal, after removal from its shell, should be secured to a small sheet of weighted cork by means of a few pins, and then covered with water in a shallow vessel of any kind.

A bristle may be passed through the pulmonary aperture into the pulmonary cavity, the roof of which is formed by the mantle. On opening this cavity a number of blood-vessels may be seen thickly distributed on its walls; and it is here that the colourless blood takes its supply of oxygen, and gives up carbonic acid gas to be expelled with the expired air.

Projecting into this cavity may be seen the somewhat tongue-shaped renal organ, an excretory organ which performs a function similar to that performed by the kidney of higher animals.

Close beside this is the heart, which consists of two cavities, the auricle and the ventricle. It receives the aërated blood from the breathing organ, and pumps it through the vessels which convey it to all parts of the body.

The digestive system may be traced by a careful dissection commenced at the mouth. On the upper side of this is the horny jaw or 'beak' already mentioned; and on the lower side of the cavity beyond it, is the rounded mass which bears the *lingual ribbon.*

A portion of this ribbon should be removed for examination under the microscope, and then the dissection may be continued along the *œsophagus* or *gullet,* which soon widens out to form the *crop.*

At the sides of the crop are the large *salivary glands,* which secrete a digestive fluid called the saliva. This fluid is conveyed through narrow ducts into the cavity of the mouth, where it mingles with the food, and gradually converts the starch into a kind of sugar.

Beyond the crop the digestive tube becomes narrow again, but it soon expands once more, forming the stomach. It then turns sharply, narrows again, and forms the intestine, which terminates at the anus—an opening which has already been mentioned as situated in the collar, close beside the pulmonary aperture.

The intestine is not a straight tube, but describes an S-shaped bend inside the digestive gland, part of which occupies the very apex of the shell. This large gland prepares a digestive fluid which is conveyed into the stomach, and has the power of dissolving food substances that are not changed by the saliva.

As regards the nervous system of the snail, we find no essential differences between it and that of the anodonta. There are three distinct masses of nerve substance. The largest of these ganglia encircles the digestive tube just behind the œsophagus, and sends nerves to the tentacles and other parts of the head. The other two supply nerves to the mantle, the foot, and the various internal organs.

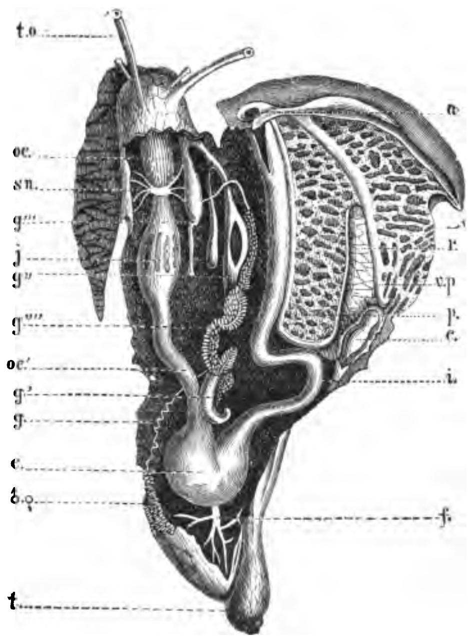


FIG. 125.—ANATOMY OF THE SNAIL

to, tentacles bearing eyes; *oe*. œsophagus; *sn*, nerve ganglion; *j*, gizzard; *e*, stomach; *t*, liver; *f*, bile ducts; *i*, intestine; *a*, anus,; *r*, kidney; *vp*, pulmonary vein; *p*, pulmonary organ; *c*, heart.

There is yet much to be learnt concerning the sensory organs of the snail. The eyes, we have seen, are situated at the tips of the longer tentacles. The organs of sound are two small sacs which lie close to the nerve ganglion of the foot. They contain a fluid, in which float a large number of little particles of calcareous substance that are set in motion by waves of sound. In this condition they strike against the exceedingly fine nerve-endings that lie in the walls of the sacs, and the impulse thus given travels along nerve fibres which eventually reach the ganglion that surrounds the digestive tube, causing the sensation of sound.

The shorter antennæ are certainly very sensitive to touch, and by some they are supposed to be the seat of the sensation of smell; but with regard to this, as well as to the sensation of taste, we have no definite knowledge.

Having now briefly examined a type of each of the two great divisions of the mollusca with which we are at present concerned, we will proceed to notice some of the more important distinguishing characteristics of our native freshwater species, chiefly with the object of enabling the reader to identify the specimens that come under his observation.

Freshwater Bivalves

The British Lamellibranchs include representatives of three families, and number fifteen species.

The three families are named respectively *Sphæriidæ*, *Unionidæ*, *Dreissenidæ*.

Before looking into the details of structure by which we identify the various species of these groups, it will be advisable to note those broader features which are common to the members of each family.

It must not be supposed for a moment that one who has the power of naming shells at sight is necessarily well acquainted with the natural history and structure of the objects named. The most interesting and most instructive study for a naturalist is that of the affinities and relationships of the various creatures that are brought under his notice. It matters little, indeed, whether the names of the species be known at all, but it is highly important that the student should be able to give each creature, after examination, its proper place in the scale of life.

Let us see, then, how we are to distinguish between the three families of our freshwater lamellibranchs.

The *Sphæriidæ*, in the first place, may be readily known by their small size, the largest species measuring only a little over three-quarters of an inch in length.

The shell is nearly spherical in form, and the hinge has both cardinal and lateral teeth.

The mantle of the animal is open in front, and at the anterior end there are either one or two siphons. There are also two gill-plates on each side, as we observed in the case of *Anodonta*, but in the present family they are unequal.

The young are hatched in the cavity of the internal gills, and only a few are accommodated by the parent at any one time.

The animals of this family are more active than the larger bivalves, and particularly so while young. The foot is large in proportion to the size of the animal, and is capable of considerable extension.

It is interesting to watch the movements of these little molluscs, and this may be easily done by putting a few into a glass of water with a tuft of pondweed.

At first the foot is thrust gradually forward. Of course this organ becomes thinner and thinner as its length is increased; and the extension is so great in the case of some of the smaller species that the foot becomes two or three times the length of the shell, and so thin and transparent that it is hardly visible.

The animal is now apparently inactive for a moment, but it is really engaged in obtaining a good foothold; and then follows the contraction of the foot, which quickly pulls the shell quite up to the point where its extremity was, for the time, fixed.

By a repetition of this manœuvre, the animal makes a series of long strides; and it is surprising what ground it can cover within a short time. It can climb the weeds with the greatest of ease, and often makes its way quite to the surface of the water.

Its progress is probably assisted by the irregularities of the surface on which it travels, these irregularities serving to give a 'purchase' to the foot; but it will be observed that these little molluscs can move with apparently the same ease on a smooth and polished surface. Thus they will at times creep up the glass of the aquarium in which they are placed, even when the surface is perfectly clean and free from any vegetable deposit.

In this case it seems that the extremity of the foot must be held by suction, and this appears more probable when the movements of the creatures are observed through the glass by means of a magnifier, for the end of the foot then presents to the glass a small circular flat surface, which reminds one of the sucking discs of the leech.

The British species of the *Sphæriidæ* inhabit ponds, ditches, and sluggish streams, and seem to thrive best on a muddy bed. They are not found in rapid rivers; and, as far as my own experience goes, they are seldom seen in ponds with clean sandy or gravelly bottoms, even when extremely abundant in mud pools in the immediate neighbourhood. This of course is not necessarily a proof of a mere mud-loving propensity, but may simply show that the muddy bottom is capable of affording the food which these small molluscs require.

Before passing on to a brief notice of the two other families of our freshwater bivalves, a digression may well be made for a short time in order to say a few words on the interesting subject of migration.

An excavation is, we will suppose, made in a certain locality; and this, filled with rain and water from the drainage, becomes a permanent pond.

As soon as the water begins to collect, pond life of various kinds makes its appearance. Here are numerous microscopic forms, aquatic insects, batrachians, and, after a time, even molluscs! Now, it is easy to account for the appearance of the greater proportion of this new population. The microscopic forms are easily carried considerable distances by wind. Winged insects travel over great distances from one pond to another, and deposit their ova on weeds, or on the surface of the water itself. Frogs, toads, and newts, too, are famous nocturnal travellers, and may often be seen considerable distances from the nearest piece of water. But how shall we account for the migration of molluscs, and especially the less active bivalves? These all breathe by gills, and the gills are not capable of absorbing the necessary oxygen unless surrounded by fluid. They can certainly live for a long time out of water, but not under the influence of a bright sun; and when they are left on dry land through the drainage or evaporation of the water in which they lived, instead of proceeding apace in search of a new pond or stream, they shrink within their shells, as if to conserve their small store of moisture till the water reaches them again.

Thus we often find, after an unusually dry season, hundreds and hundreds of dead molluscs, baked by the burning sun, lying on the parched and cracked ground which now surrounds a little puddle—the only remains of what was, a few weeks before, a comparatively large pond.

How, then, shall we account for the appearance of molluscs in a new pond, a mile or more perhaps from the nearest pond or stream?

Here is at least a part of the solution to the problem. Wading birds, which obtain their food from marshes and the banks of ponds and rivers, have been found, when shot, to have a bivalve shell attached to one of the claws. The explanation is simple. The bird, while wading in the mud in search of food, happened to thrust one of its claws between the gaping valves of a mollusc. Under these circumstances, the mollusc would of course close its valves with all its might on the intruder.

The sequel to this is plain. The bird presently takes to flight, carrying the bivalve to some other piece of water, perhaps many miles away, and thus possibly conveying a species to a new locality.

I have reason to believe, too, that batrachians may do much towards the distribution of bivalves, and in a similar manner; for while pond hunting I have captured several frogs and toads with bivalves (*Sphærium corneum*) clinging firmly to their toes.

Some small ponds and ditches are particularly rich in this species of the bivalves; and it is also interesting to note that many of the frogs which are captured in the neighbourhood of these have imperfect toes—toes which evidently have been bitten or clipped in some way or another. And when one remembers the power of the adductor muscles which close the bivalve shells, also the sharpness of the edges of the valves, and the persevering tenacity with which a bivalve will hold on to an intruder who happens, accidentally or otherwise, to encroach within its domain, it seems highly probable that the missing portions of the frogs' toes have become the property of bivalves which may, in some instances at least, have been transported a considerable distance by the unwilling carrier.

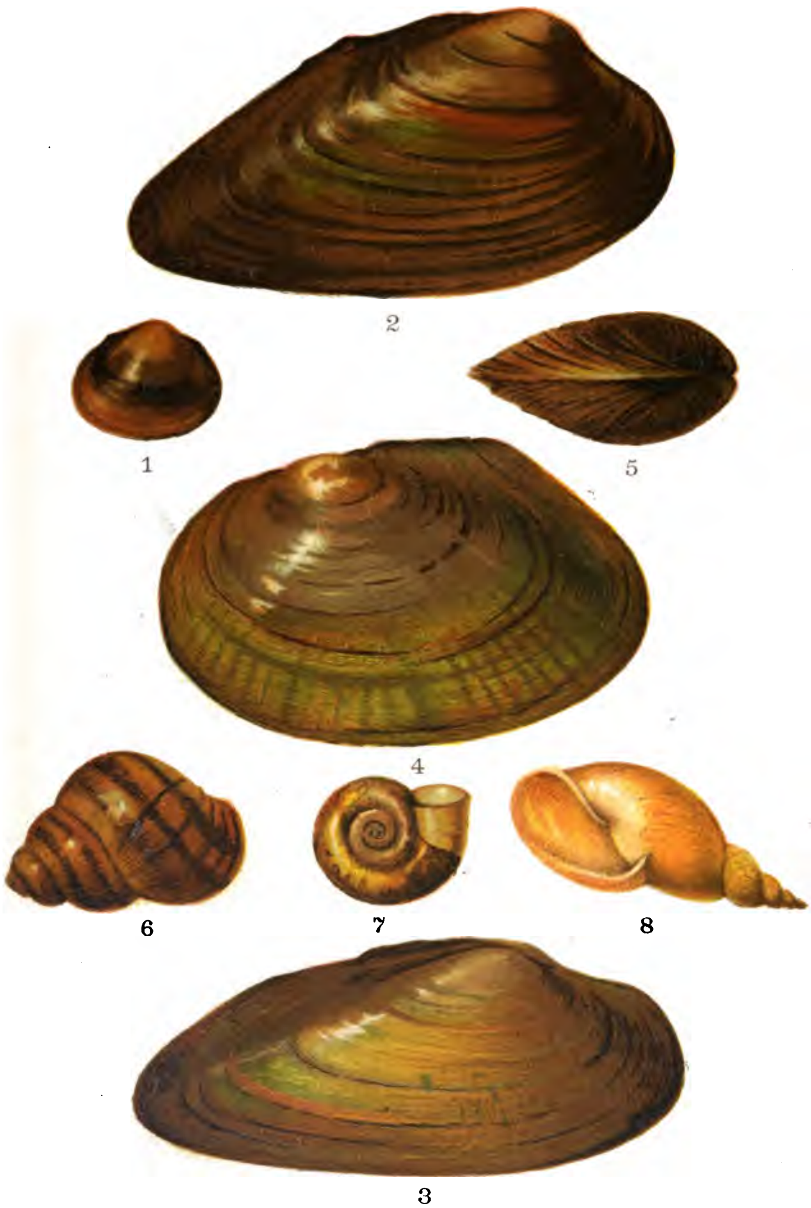
The second family of our freshwater bivalves is termed the *Unionidæ*. It includes only five native species, all of which attain considerable dimensions. The smallest of them exceeds two inches in breadth, while the largest often reaches eight or nine inches.

The shell is oval or elongated. The valves are equal, but not equilateral. In some species the teeth, both cardinal and lateral, are strongly developed; but in others are entirely wanting. The ligament is external, and very conspicuous; and the muscular impressions are very distinct. These latter include the impressions of the adductor muscles—anterior and posterior—also of two pedal muscles at the anterior and one at the posterior end of the shell.

The edges of the mantle are quite free except at the posterior end, where they unite to form the two siphons.

The members of this family are found chiefly in ponds, lakes,

PLATE II.



West, Newman imp.

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Order [illegible]

Gills leaflike, two on [illegible]
mantle.

1. Shell small and an[illegible] and lateral teeth. [illegible] the anterior end. [illegible]
2. Shell large, oval [illegible] teeth. Body with [illegible] open.
3. Shell boat-shaped. [illegible] bluntly keeled. [illegible] Animal provided with [illegible]

Family [illegible]

We will now note the chief [illegible] of each of the three families [illegible] *Sphæriidæ*.

In the first place, however, it must be observed that the British members of this [illegible] divided into two genera, named respectively *Sphærium* [illegible]*ium*. The shells of the former genus are equilateral [illegible], the hinge being at or very near the middle of the d[illegible]. There are two small cardinal teeth in the right valve [illegible] left. The lateral teeth are elongated, and number o[illegible] in the right valve, and two on each side in the le[illegible] has two siphons at the anterior end, and the oute[illegible] than the inner.

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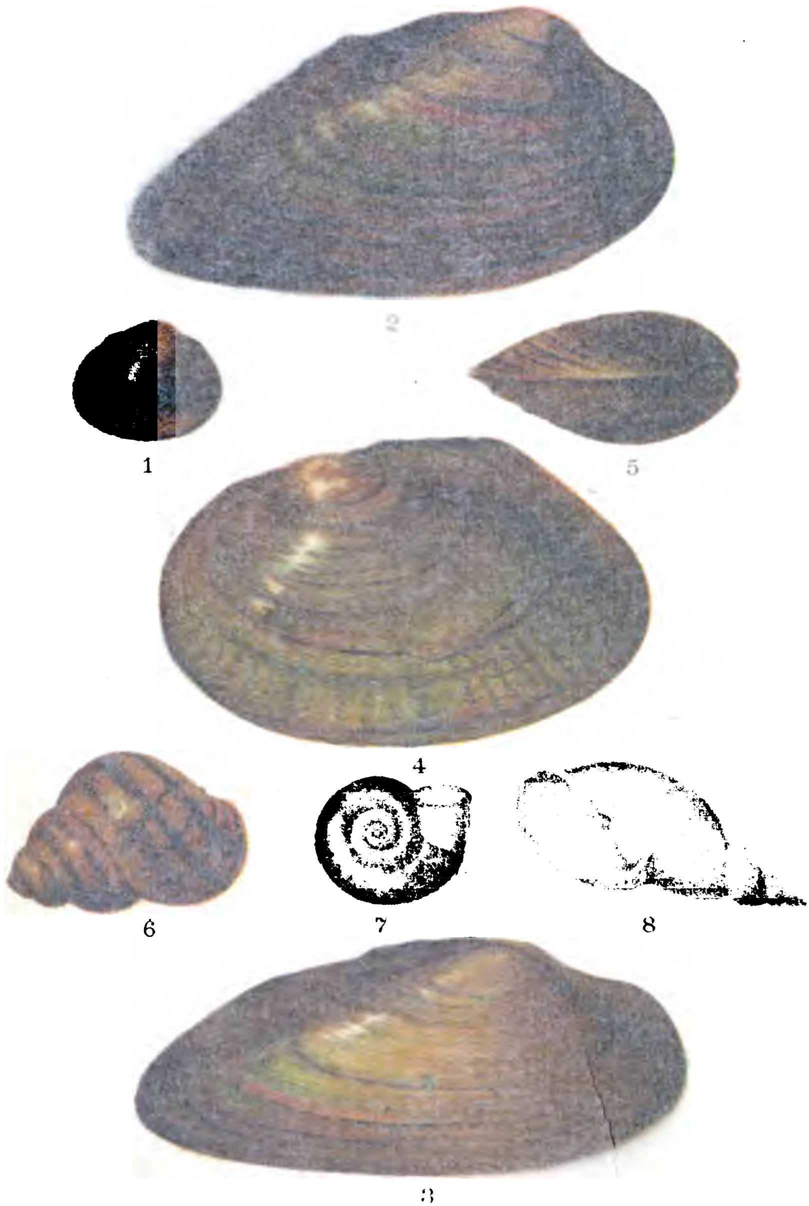


and sluggish and muddy streams; but one (*Unio Margaritifer*) inhabits rapid rivers and mountain torrents.

The third family (*Dreissenidæ*) has only one British representative. Its shell is somewhat mussel-shaped, but very decidedly triangular. The umbones are at the extreme end of the shell, and the valves are bluntly keeled in such a manner as to give the shell the appearance of a small wide boat.

The animal differs from those of the two preceding families in that the mantle is closed with the exception of a small orifice through which a byssus (page 137) protrudes.

The following table shows at a glance the chief distinguishing features of the three families just alluded to, and will materially assist the reader when grouping his specimens:

Order *Lamellibranchiata*

Gills leaflike, two on each side, between the body and the mantle.

1. Shell small and almost globular. Hinge with both cardinal and lateral teeth. Body with either one or two siphons at the anterior end. Mantle open. Family SPHÆRIIDÆ.
2. Shell large, oval or elongated. Hinge with or without teeth. Body with two siphons at the posterior end. Mantle open. Family UNIONIDÆ.
3. Shell boat-shaped. Umbones at extreme end. Valves bluntly keeled. Teeth small or absent. Mantle closed. Animal provided with a byssus. Family DREISSENIDÆ.

Family SPHÆRIIDÆ

We will now note the chief characters of the individual species of each of the three families of bivalves, commencing with the *Sphæriidæ*.

In the first place, however, it must be observed that the British members of this family are divided into two genera, named respectively *Sphærium* and *Pisidium*. The shells of the former genus are equilateral or nearly so, the hinge being at or very near the middle of the dorsal border. There are two small cardinal teeth in the right valve, and one in the left. The lateral teeth are elongated, and number one on each side in the right valve, and two on each side in the left. The animal has two siphons at the anterior end, and the outer gills are smaller than the inner.

In *Pisidium* the shell is not equilateral, the anterior side being longer than the posterior. The teeth are the same as in *Sphærium*, but are more strongly developed in proportion to the size of the shell The animal has only one (exhalent) siphon.

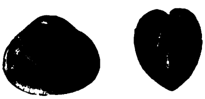


Fig. 126.—*Sphærium corneum*

Perhaps the commonest and most widely distributed species of the *Sphærium* genus is *S. corneum*, which may be dredged out of ponds, ditches, and sluggish streams almost everywhere, and is so abundant in some places that scores may be obtained at a single haul.

The shell is of a brownish colour, finely grooved along the lines of growth, and often prettily banded with a darker or a lighter colour. The length of the full-grown specimen is about half an inch, the width nearly five twelfths of an inch, and the thickness one-third of an inch. The umbones are very blunt, and the ligament is hardly visible from the outside.

The young of this species are very different from the adult in form, and may be easily mistaken by the inexperienced shell-collector for a different species. They are not nearly so thick and spherical as the adult, and the umbones are not so prominent.

The largest species of the genus is *S. rivicola* (Plate II, fig. 1), which measures more than three-quarters of an inch in length. In general form it resembles the last species, but is not quite so swollen; and its shell, which varies in colour from a pale yellow to a rich olive-green, is often conspicuously marked by bold dark bands. It is more deeply grooved along the lines of growth than *Corneum*, and its ligament is distinctly visible from the outside. This species may be found in sluggish and muddy streams, but is not nearly so widely distributed as the preceding. Its chief haunts are the slow rivers and the canals of the south of England. It is less abundant in the north, and does not seem to have been met with in Wales, Scotland, or Ireland.

Fig. 127.—*Sphærium ovale*

The third species—*S. ovale*—is much more local; and, although moderately common in ponds and ditches in the neighbourhood of London, it has been taken in only a few of our counties, and not at all in Wales, Scotland, and Ireland.

Its shell is oblong, of about the same length as that of *S. corneum*, but not nearly so swollen. The umbones are small; the ligament very narrow, but visible on the exterior; and the lines of growth are very finely grooved. The colour is very pale grey, often yellowish or brownish.

The last species of the genus is *S. lacustre*, which is widely distributed in the English counties, though not known in Scotland or Ireland. It is the smallest of the four, being only about a third of an inch in length, and is, like the last species, more compressed than *Corneum* and *Rivicola*.

FIG. 128.— *Sphærium lacustre*

The colour is very pale yellowish grey; and, as will be observed by the illustration, the general form is somewhat squarish or rhomboidal, with narrow and prominent umbones. The shell is finely striated, and the nucleus covers the umbones as with a small whitish cap.

The next genus (*Pisidium*) includes five small species, the largest of which does not exceed *S. lacustre* in size.

They are readily distinguished from the preceding by their unsymmetrical form, the umbones being considerably removed from the middle line, and the anterior side longer than the posterior. The animals also have only one siphon, viz. that for the exhalent current.

The largest species of this genus (*P. amnicum*) has a triangular brownish or grey shell, with blunt umbones, and rather deep grooves along the lines of growth. The teeth resemble those of the genus *Sphærium*, but are more strongly developed in proportion to the size of the shell; and the length of the full-grown shell is only one-third of an inch. The ligament is short and narrow, but is very distinctly visible from the outside.

FIG. 129.—*Pisidium amnicum*

Taking the species in order of size, the next is *P. fontinale*, which measures hardly one-fifth of an inch in length. It is more swollen than *Amnicum*, and the shell is not so coarsely grooved. The umbones, too, are narrower and more prominent. *Pusillum*, the next species, is less than one-sixth of an inch in length, and the shell is oval rather than triangular; neither is it so unsymmetrical as the two preceding species, for the

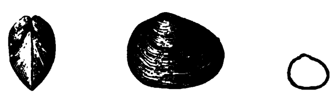


FIG. 130.—*Pisidium fontinale*, ENLARGED

umbones, which are blunt and short, are nearly in the middle of the dorsal margin.

The two remaining species (*P. nitidum* and *P. roseum*) are very small, being only one-tenth of an inch in length. Both are found in ponds and ditches, often in each other's company, and it is hardly possible for one to distinguish between them without the aid of a lens.

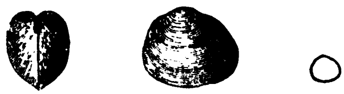


FIG. 131.—*Pisidium pusillum*, ENLARGED

When carefully examined, however, it will be observed that *Roseum* is oblong in form, while *Nitidum* is more globular. The shell of the latter, too, is smooth and shining, and is thickest near the dorsal margin; but the former is deeply grooved, with rather prominent umbones which are so far out of the centre that the anterior portion of the shell is much longer than the posterior.

FIG. 132.—*Pisidium nitidum*, ENLARGED

FIG. 133.—*Pisidium roseum*, ENLARGED

As a further aid to the identification of these five small shells it may be mentioned that the ligament of the shell is conspicuous only in *Amnicum*, and quite invisible from the exterior in *Nitidum* and *Pusillum*.

The following table will assist the reader in naming his specimens of the Sphæriidæ family, but he must be prepared to meet with variations in most of the species, the nature of which there is not space to describe.

Family SPHÆRIIDÆ

I. Genus SPHÆRIUM.—Shell equilateral or nearly so. Animal with two siphons.
  (*a*) Shell brownish or yellowish; swollen in middle. Umbones blunt.
    1. Finely grooved. Ligament invisible from exterior. Length half an inch. *S. corneum.*

2. Strongly grooved. Ligament conspicuous. Length three-quarters of an inch. *S. rivicola.*

(*b*) Shell whitish or greyish; compressed. Umbones small.

3. Oblong; finely grooved. Ligament visible externally. Length half an inch. *S. ovale.*

4. Squarish. Umbones narrow, prominent, and capped. Ligament hardly visible. Length one-third of an inch. *S. lacustre.*

II. Genus PISIDIUM.—Shell inequilateral. Animal with one siphon.

(*a*) Shell triangular; swollen.

1. Strongly grooved. Umbones blunt. Ligament conspicuous. Length one-third of an inch. *P. amnicum.*

2. Finely grooved. Umbones pointed. Length one-fifth of an inch. *P. fontinale.*

(*b*) Shell finely grooved. Ligament not visible externally.

3. Shell oval. Umbones blunt and almost central. Length one-sixth of an inch. *P. pusillum.*

4. Shell roundish, shining. Dorsal part swollen. Length one-tenth of an inch. *P. nitidum.*

(*c*) Shell oblong; strongly grooved, swollen in middle. Length one-twelfth of an inch. *P. roseum.*

When describing the Freshwater Mussel (*Anodonta*) as a type of the bivalves, in the early pages of this chapter, we referred to the remarkable prolificacy of this animal, which is capable of producing, and accommodating within its gills hundreds of thousands of its young. These young, it will be remembered, leave the body of the parent while still very minute, and make use of the locomotive power of a larger animal, by attaching themselves to it, until they are able to start a career for themselves.

It is very different, however, with the *Sphæriidæ*. In this family the number of young within the parent seldom exceeds twenty at any one time; and, instead of leaving the body of the parent at an early stage, they often claim maternal protection till they have attained quite a quarter of their full length.

Family UNIONIDÆ

We have already become somewhat familiarised with this family by our brief examination of one of its members—*Anodonta.*

The term *Unionidæ* is derived from *unio*, which signifies 'a pearl,' and is supplied on account of the formation of pearly or nacreous matter, both in the shells, and also in the soft structures of the animals forming the group.

The shell really consists of three layers, the structure of which may be seen by examining a vertical section under the microscope.

The outer layer is thin, and is composed of a horny substance.

The middle one is comparatively thick, and consists of a number of small polygonal columns or prisms, all arranged parallel with one another, at right angles to the surface of the shell, and connected by inward extensions of the outer horny covering. This layer is generally spoken of as the prismatic layer.

The inner layer is composed of nacreous substance which, when polished, is termed 'mother of pearl.'

The nacreous matter is formed by alternate layers of calcium carbonate (also called carbonate of lime) and animal substance, both in the form of exceedingly thin laminæ; and the peculiar pearly lustre of the shell is partly due to this structural arrangement. If, however, a thin section of the nacre be examined, it will be found that the thin layers above mentioned are minutely waved or undulated, and this fact has undoubtedly much to do with the production of the pearly lustre.

If a nacreous shell, or a piece of the nacreous layer of a shell, be steeped for a short time in dilute hydrochloric acid, the calcium carbonate will be entirely dissolved out, leaving a porous mass of membranous animal matter, of the same form as the original shell or fragment.

Pearls proper are globular masses of substance that are formed in the muscles and other soft structures of the animal. They occur in various species of oysters and mussels, both freshwater and marine, and are often so highly esteemed that the 'pearl fisheries' have taken a prominent place among the industries of certain countries.

The finest pearls are obtained from marine species, but river mussels have also yielded very valuable specimens, in illustration of which may be cited the once famous Scotch pearl fisheries, carried on principally in the river Tay.

The structure of a pearl closely resembles that of a nacreous shell, the same three layers being discernible, but with their order reversed—that is, the outer layer of the pearl corresponding with the inner one of the shell.

The nucleus of the pearl generally contains a speck of organic matter. This is surrounded by a layer of calcareous substance, upon which are deposited alternate layers—exceedingly thin laminæ—of mineral and animal matter.

These layers are generally much thinner than in the nacreous layer of the shell, and are also more transparent; and this, and the minute corrugations into which the laminæ are moulded, are probably the cause of the beautiful iridescence that enhances the value of the gem.

The colours of pearls vary considerably with the species in which they are found, green, pink, violet, and other shades being more or less common; and it appears, too, that the formation of pearls in any one species varies considerably according to local circumstances and other causes which seem to be but little understood.

In connection with this latter statement it is curious to note that out of a number of bivalves, all of one species, and taken from the same bed, a few may have developed pearls, while all the others, reared under exactly the same circumstances, show no signs of them. An attempt to explain this has been given us in the statement that certain individuals have a predisposition to develop pearls.

Such a statement may at first seem to be meaningless, but we must remember that pearl development is to be regarded as a disease, being the result of an irritation applied to one or other of the soft animal structures; and most of us are willing to admit that such predispositions to develop certain diseases are to be met with among our own kind.

It has been asserted that pearls are always the result of a deposit of animal and mineral substance round a grain of sand which has become lodged in a soft tissue; also that the Chinese increased their takings of the gems by first securing the bivalves, charging them with grains of sand, and then replacing them in the water for the irritant to do its work.

Others are of opinion that the irritation is the result of foreign organic matter, such as small animals that are taken into the system with the water current of the inhalent siphon, or of internal parasites; but whether this be so or not, it is certain that only a very small proportion of those pearl-producing bivalves which are found with grains of sand within them are capable of producing pearls.

We must now notice the distinguishing features of the British *Unionidæ* or pearl producers.

These are all large molluscs, with oblong or elongated shells, the valves of which are equal but not equilateral. The prismatic layer is not very thick, but the 'epidermis' or outer horny layer, which is usually of an olive or brown colour, is strongly developed.

The ligament is external and very conspicuous, and aged shells are often thickened by heavy deposits of nacreous matter, and are also frequently very much eroded or worn away.

In some species teeth are entirely wanting, but where these exist, the cardinal teeth are usually large, and the laterals either striated or laminar.

The mantle lobes are free at their edges, except at the posterior end, where they are united to form the two siphons, as we observed in the case of *Anodonta*; and the foot is large and tongue-shaped.

The British species contain representatives of two genera—*Unio* and *Anodonta*—and number in all only five, three belonging to the former, and two to the latter genus.

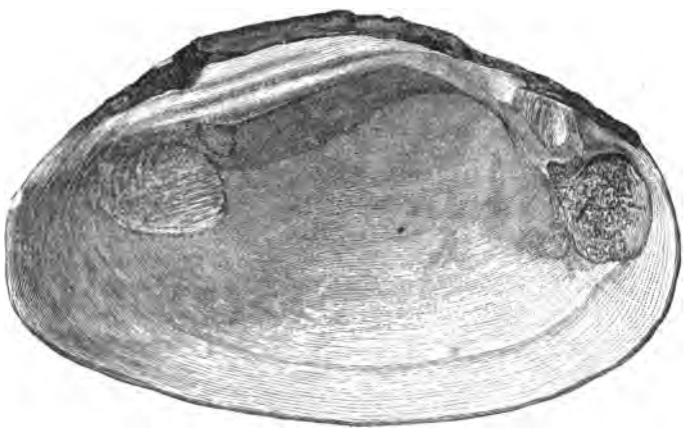


FIG. 134.—VALVE OF *Unio Margaritifer*, SHOWING THE TEETH AND THE MUSCULAR IMPRESSIONS

The two genera may be easily distinguished as follows: In *Unio* the shell is very strong and solid, particularly the aged specimens. The cardinal teeth are usually large ; and the lateral teeth, which exist on the anterior and posterior sides of both valves, are laminar in structure, and those on the posterior side are the longer.

In *Anodonta* the shell is somewhat similar in general form, but is much thinner, and there are no teeth. The valves of young specimens are compressed, but as age advances they become ventricose or swollen in the middle.

The three species of *Unio* are often called the river mussels, being obtained chiefly by dredging in running water ; but two of them—*U. tumidus* and *U. pictorum*—may be found in large ponds and lakes as well as in streams. These two are pretty widely distributed in England, and have also been taken in Montgomeryshire in Wales, but are not known in Scotland or Ireland.

The other—*U. Margaritifer*—is met with in the gravelly beds of rapid streams and rivers of the mountainous districts of the north of England, Wales, Scotland, and Ireland ; but is not found in the south.

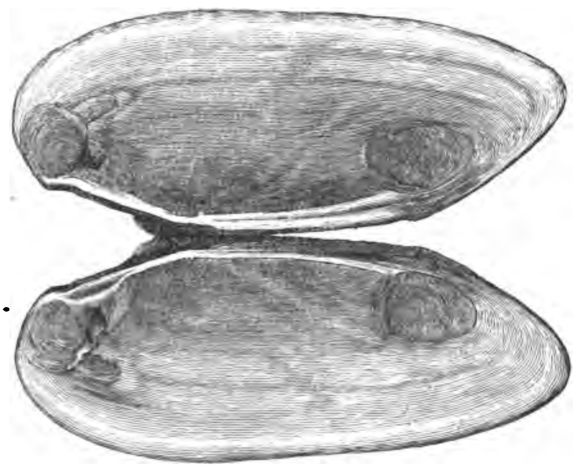


FIG. 135.—SHELL OF *Unio pictorum*, SHOWING THE TEETH

The reader will be able to identify *U. tumidus* and *U. pictorum* by the aid of the illustrations on Plate II, where it will be observed that the former shell is of an oblong form, and the latter a more elongated oblong. The umbones of *U. tumidus* (Plate II, fig. 2) are rather prominent and wrinkled, while those of *U. pictorum* (Plate II, fig. 3) are not so prominent nor so wrinkled, and the ligament is longer than in *U. tumidus*. There are also differences in the form of the teeth, the anterior set of *U. tumidus* being prominent and conical, while those of the other species are compressed.

U. Margaritifer is a very dark brown shell, ovate in form, thick and heavy, and attains almost twice the length of the two preceding species, both of which rarely exceed three inches.

The two species of *Anodonta—Cygnea* (fig. 136) and *Anatina* (Plate II, fig. 4)—are very similar in external appearance, but the

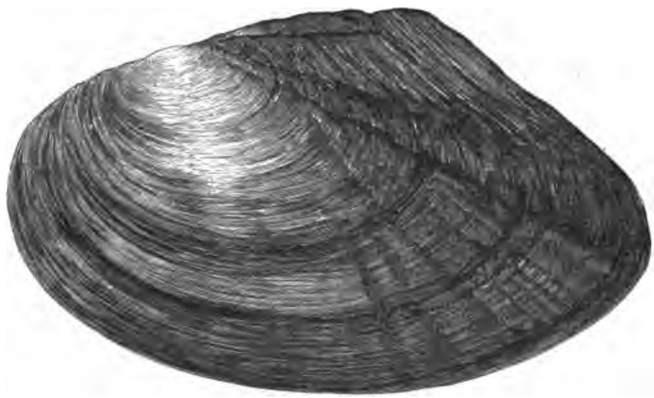


FIG. 136.—*Anodonta cygnea*

latter is much smaller, seldom exceeding three and a half inches in length, while *Cygnea* sometimes reaches eight or nine inches. The shell of *Anatina*, too, is more glossy, and more compressed above and behind; and the ligament is decidedly shorter than that of *Cygnea*. Both species are found in ponds, lakes, canals, and slow rivers, and are widely distributed in England. They have also been taken in a few counties of Wales, Scotland, and Ireland; but *Anatina* is more local than *Cygnea*.

Family DREISSENIDÆ

This family is named after Dreyssen, a Belgian naturalist, and has only one British representative—*Dreissena polymorpha*

(Plate II, fig. 5)—really a native of the East, inhabiting the rivers which flow into the Caspian and the Sea of Aral.

It was introduced into England in the early part of the present century, probably attached by its byssus to imported timber. It was first discovered in the Surrey Docks, and has since spread into the canals, rivers, and ponds of many of the English counties, and into a few districts in the south of Scotland.

Fig. 137.—*Dreissena polymorpha*

The shell is somewhat mussel-shaped, but triangular, with the umbones at one end. Both valves are bluntly keeled, and the right one has an opening through which the byssus and the foot protrude. The ligament is internal, and the teeth are either small or absent.

The shell is a pretty one, the colour being yellowish or greenish brown, and marked with zigzag transverse bands of dark brown or brownish purple.

The animal has a closed mantle.

Freshwater Univalves

We have now to consider the other great division of the *Mollusca*, of which the common snail was chosen as a type.

This division, it will be remembered, is termed the *Gasteropoda*; and, since the greater number of its members are protected by a single calcareous shell, the whole are often spoken of collectively as the *univalve molluscs*.

In some the shell is entirely wanting; in others it is represented by a few granules of calcareous matter or a small plate of the same material, which may or may not be concealed beneath the surface of the mantle.

In all, the body has a distinct head, with one or two pairs of tentacles, and eyes situated on the summits or at the bases of these appendages.

Many of the *Gasteropods* are terrestrial in their habits, and these all breathe by means of lungs, like the common snail; but a very large number inhabit salt, brackish, and fresh waters, and these breathe partly by lungs and partly by gills.

We observed that the common garden snail closed its shell, at intervals of rest and during periods of hibernation, by means of a slimy mucus that is secreted by the mantle, thus fixing its shell on the surface to which its foot was attached, and securing itself to a certain extent from its foes.

But many of the univalves have a lid of horny or calcareous matter attached to the back of the foot in such a manner as to partially or completely close the mouth of the shell when the animal retires within.

This lid is called the *operculum*, and must be familiar to every one who has seen the common periwinkle or one of its edible relatives.

If we examine an operculum we find that it is marked with striations more or less distinct. These are generally closed curves, one within another, and all surrounding what is called the nucleus.

The nucleus represents the original operculum of the young shell, and the striations surrounding it are the lines of growth, marking the areas added successively as the shell increased in size.

Thus it will be understood that the operculum increases in size by additions at its circumference; and if the growth is equal on all sides, the nucleus remains *central*; but if the additions are made more rapidly on one side, the nucleus becomes *excentric*.

The British aquatic univalves represent two distinct orders—the *Pectinibranchiata* or comb-gilled, and the *Pulmonobranchiata* or lung-breathers.

In the former the shell is spiral and its mouth operculated. In the latter the shell is also spiral, at least as far as the British *aquatic* species are concerned, but the mouth is usually non-operculated.

The *Pectinibranchs* include three families—the *Neritidæ*, the *Paludinidæ*, and the *Valvatidæ*.

The Neritidæ have thick semiglobular shells, with a small compressed spire at the side. The shell is composed of about three whorls, but the first and second of these are exceedingly small compared with the body whorl. The internal cavity does not exhibit that complexity of structure common to most spiral shells, the internal parts of the shell having been absorbed. The aperture, however, is partially closed by a flat expansion of the shell on the columellar side, thus giving the mouth a semilunar form (fig. 138). The operculum is calcareous. The animal has long and slender tentacles, and the eyes are mounted on pedicels at their bases. The foot is triangular or oblong.

The second family—*Paludinidæ*—is characterised by a conical or globular shell, usually of an olive-green colour. The mouth is oval, and its margin (*peristome*) is complete. The operculum is sometimes horny and sometimes calcareous. The gills are internal, the tentacles long and slender, and the eyes are either sessile (not stalked) or mounted on small pedicels at the base of the tentacles.

The third family—*Valvatidæ*—has a conical shell, which is sometimes so depressed that it is almost discoidal. The mouth is circular, with a complete peristome, and the operculum is horny. The tentacles, two in number, are long and slender, with eyes situated at their bases. The animal breathes by means of long plumelike gills, which are partially protruded on the right side when it is crawling.

The following table will assist the reader in grouping his shells into their respective families, previous to the determination of the genera and species:

Order *Pectinibranchiata*

Shell spiral. Mouth closed by an operculum. Animal breathes by gills.

(*a*) Shell semiglobular; spire flat; mouth semilunar.
Family NERITIDÆ

(*b*) Shell conical or depressed; peristome almost complete.

1. Shell swollen; mouth oval; gills internal.
Family PALUDINIDÆ

2. Shell depressed (conoid or discoid); mouth round; peri stome complete; gill long, plumelike, protrusile.
Family VALVATIDÆ

Family NERITIDÆ

This family contains only one British species—*Neritina fluviatilis*, which is found attached to stones at the bottom of rivers and canals in many parts of England, and in a few localities in Scotland and Ireland.

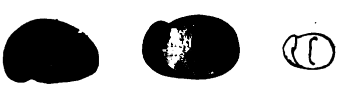


FIG. 138.—*Neritina fluviatilis*

The shell is ovate in form, of a yellowish, grey, or brownish colour, and generally chequered with little elongated patches of various tints. The operculum is semilunar, yellowish, with orange round the edge; and on its under side is a spiral projection. Our illustration of the shell is twice the natural dimensions, the real size being denoted by the outline drawing.

Family PALUDINIDÆ

This family contains the genera *Paludina* and *Bithynia*, in each of which we have but two species.

The eggs of *Paludina* are hatched within the body of the parent; and during the early part of the summer, the young, in different stages of development, may be dissected out, some of them being quite a quarter of an inch in length.

The whorls of the shell are very convex; the mouth is angulated on the outer side; and the operculum is horny, with concentric lines of growth.

FIG. 139.—*Paludina vivipara*

FIG. 140.—*Paludina contecta*

The commonest species—*P. vivipara*—is found in ponds, canals, and slow rivers in many parts of England, but does not seem to have been taken in the sister countries. It may be readily recognised by reference to Plate II, fig. 6, and the accompanying woodcut shows the form of the mouth and operculum, and the narrow slit representing the umbilicus.

The other species—*P. contecta*—is slightly larger; and the ground colour, which is darker, is relieved by brown bands as in *Vivipara*. The whorls of the shell are more rounded, the suture deeper, and the umbilicus more distinct. This species, though not so widely distributed as the last, is found in ponds and canals in many parts of England.

The two shells of the genus Bithynia are very much smaller;

the larger—that of *B. tentaculata*—being half an inch in length, and the smaller (*B. Leachii*) only a quarter of an inch.

Both these species are oviparous, and both are easily reared in an indoor aquarium. The eggs are laid in regular bands on the

FIG. 141.—*Bithynia tentaculata*

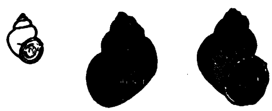


FIG. 142.—*Bithynia Leachii*, ENLARGED

stones and weeds in ditches and sluggish streams; and, in the artificial aquarium, frequently on the glass. It has been said that the mollusc invariably cleans the surface on which it deposits its eggs. This it undoubtedly does as a general rule, and the operation may be watched most readily when the glass of an aquarium is chosen as the material on which to lay; but I have often seen the eggs of *B. tentaculata* deposited on such a dense confervoid growth that they were hardly visible when viewed from the outside of the aquarium. The animals are full grown in the spring of their second year.

The operculum of *Bithynia* differs from that of *Paludina* in that it is impregnated with carbonate of lime, and is therefore hard and brittle, while that of the latter genus is horny and flexible.

The smaller species may be distinguished from *B. tentaculata* by the following marks: the shell has only about four and a half whorls, while that of *B. tentaculata* has six. The whorls are more swollen, and separated by a deeper fissure. The mouth is almost circular, while that of the other species is oval, and angular above. In *B. Leachii*, too, there is an umbilicus, but this is absent in *Tentaculata*.

Both the shells are widely distributed, the larger being found in all the divisions of the United Kingdom. They are mostly met with in the southern counties, and *B. Leachii*, which is more restricted than *Tentaculata*, has not been taken in Scotland or Ireland.

A third genus, called *Hydrobia*, is often included in this family. It contains a shell (*H. similis*) which is to be found in the Woolwich Marshes, in ditches which receive the brackish water of the Thames at each flood tide. It is somewhat like *B. tentaculata*, but the operculum is horny, and a very narrow umbilicus exists.

Family VALVATIDÆ

This family contains only two British species, and these both belong to the genus *Valvata*.

The larger of these (*V. piscinalis*) is shown in two positions in fig. 143, and the smaller (*V. cristata*) in fig. 144. In both these illustrations the reader will observe the depressed spire, especially

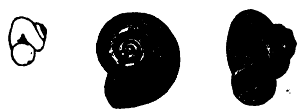


FIG. 143.—*Valvata piscinalis*, ENLARGED

FIG. 144.—*Valvata cristata*, ENLARGED

of *V. cristata*, which is so reduced in height that the shell is almost a disc. The circular mouth, with its complete peristome, will also be noticed; as well as the large and gaping umbilicus of *V. piscinalis*.

Both species are widely distributed in Great Britain, *Piscinalis* appearing to have the greater range; but it is doubtful whether the small size of *Cristata* does not cause it to be frequently overlooked when its larger relative would have been seen and secured.

We will conclude our remarks on the *Pectinibranchs* by giving the reader a tabular view of the whole group.

Order *Pectinibranchiata*

Shell spiral. Mouth closed by an operculum. Animal breathes by gills.

(*a*) Family NERITIDÆ.—Shell semiglobular; spire flat and lateral; mouth semilunar.

Genus NERITINA. One British species. *N. fluviatilis.*

(*b*) Family PALUDINIDÆ.—Shell conical or discoid Mouth closed by an operculum. Animal breathes by internal gills.

1. Genus PALUDINA.—Shell conical; swollen. Mouth oval; peristome almost complete. Operculum horny. Animal ovoviviparous.

A. Shell greenish. Umbilicus very narrow or absent. Mouth angulated. *P. vivipara.*

B. Shell olive-green. Umbilicus distinct and deep. Mouth nearly circular. *P. contecta.*

2. Genus Bithynia. Shell conical. Operculum shelly. Animal oviparous.

A. Shell of six whorls. Mouth angulated. Umbilicus absent. *B. tentaculata.*

B. Shell of about four whorls. Mouth round. Umbilicus distinct. *B. Leachii.*

(*c*) Family VALVATIDÆ.—Shell depressed. Mouth round. Peristome complete. Gill protrusile and plumelike.

Genus Valvata.

A. Shell subglobular. Spire compressed. *V. piscinalis.*

B. Shell discoid. Umbilicus large. *V. cristata.*

The Lung-breathing Univalve Molluscs

The lung-breathing gasteropods form the order *Pulmonifera* or *Pulmonobranchiata.*

This order includes all the land snails, slugs, and the greater number of the water snails.

The breathing organ of these molluscs is a simple pulmonary sac, like that which we observed in the case of the garden snail, surrounded by a closely set network of blood capillaries.

The shell is generally well developed, and in the form of a spiral; but in some it is conical, and in others it is merely a calcareous plate, or is represented by a few granules of a limy deposit. In some cases the mouth of the shell is closed by an operculum, but not in any of our freshwater species.

The order contains about twenty-five species that inhabit our ponds and streams, and these represent only one family—the *Limnæidæ*, of which the following are the chief distinguishing characteristics:

The shell is thin, of a yellow or brownish colour, and is either spiral or conical. The animal has a short and broad muzzle, two tentacles, and sessile eyes. The teeth are very like those of the common garden snail, and the upper mandible is also much like that of the same species.

The greater number of the *Limnæidæ* are easily kept and bred in a small aquarium. They feed chiefly on vegetable matter, both fresh and decaying; and some of them greedily attack decomposing animal matter, and are therefore likely to prove very useful at times as scavengers of the aquarium as well as of the stagnant pond.

They lay their spawn on the vegetation, stones, glass, or any other surface at hand. It is an elongated oval mass of gelatinous substance with the germs embedded in it; and being transparent the development of the young may be watched with the greatest of ease.

They hibernate in mud during the cold weather, but several of the species may be taken with the net from weeds during mild days, even in the middle of the winter.

The genera of this family, at least as far as they concern us at present, are *Planorbis*, *Physa*, *Limnæa*, and *Ancylus*; the first three including what are commonly known as 'water snails,' and the last the 'freshwater limpets.'

The flatly coiled and discoid shell of *Valvata cristata*—the last we examined of the *Pectinibranchs*—closely resembles that of the first of these genera, for the most striking characteristic of *Planorbis* is a many-whorled shell, the coils of which lie almost in the same plane. The mouth of the shell, however, differs from that of *V. cristata*, for it is either semicircular, semilunar, or crescent-shaped, and has no operculum. The peristome is also very thin, and is extended on the upper side, so that the cavity of the mouth cannot be seen from above. The animal has a short round or oval foot, and a pair of long and slender tentacles with the eyes at their bases.

The next genus is called by a name (*Physa*) which signifies a pouch. The shell is an elongated oval, very thin and glossy. The spiral is *sinistral* or left-handed (page 139); the mouth is rounded in front and has no operculum. The mantle is expanded and covers part of the shell, and in some species is edged with a fringe of long filaments. The tentacles are long and slender, and the eyes are situated at their bases.

The third and typical genus of the family is *Limnæa*, the name being derived from a Greek word which means 'a marsh.' In this division the shell is oval, with a *dextral* or right-handed spiral more or less elongated. It is thin and semi-transparent, and the mouth, which is oval or oblong, has no operculum. The animals of this genus may be readily recognised by the short and wide head, with its two *triangular* tentacles, and eyes at their bases. The foot is oval.

The last genus—*Ancylus* (*agkulos* = a small shield)—may be known at once by the conical limpet-shaped shell, the base of which is of an oblong-oval form. The cone is not symmetrical, but has its apex nearer the posterior end. The apex is also bent towards one side, and thus the shell may be regarded as a spiral, in which case it may be either *sinistral* or *dextral*. The foot is large and oval, the tentacles triangular or conical, and the eyes situated at the bases of the latter.

Again I give the chief distinguishing characteristics of the groups in such a form that they may be seen at a glance by the reader when classifying his specimens.

Family LIMNÆIDÆ

Shell thin, spiral or conical. No operculum. Eyes sessile. Animal breathes by a lung.

1. Shell spiral, discoid. Mouth semicircular, semilunar, or crescent-shaped. Genus PLANORBIS.
2. Shell oval.
   (*a*) Spiral *sinistral*. Mouth rounded in front. Mantle expanded. Tentacles long and slender. Genus PHYSA.
   (*b*) Spiral *dextral*. Mouth oval. Tentacles triangular. Genus LIMNÆA.
3. Shell conical (limpet-shaped). Tentacles conical. Genus ANCYLUS.

Genus PLANORBIS.—This genus is rather a large one, containing about a dozen British species. There is not space for a detailed

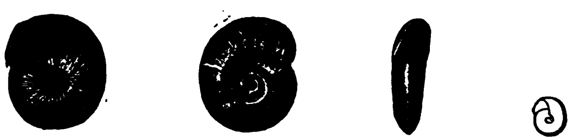


FIG. 145.—*Planorbis lineatus*, ENLARGED

description of each of these; and so, after a few general remarks, I shall put the leading characters, by which we identify the species, in a tabular form.

First, as to their distribution, most of them have a rather wide range, and some are very common in most parts of Britain.

P. albus, *spirorbis*, *vortex*, *complanatus*, and *contortus* are all widely distributed and more or less common. *Nitidus*, *Nautileus*, *Carinatus*, and *Corneus* are more local. *Lineatus* and *Parvus* are

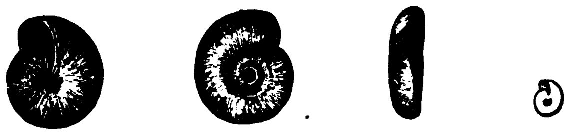


FIG. 146.—*Planorbis nitidus*, ENLARGED

very local; and *Dilatatus*, which has been introduced by the agency of our shipping trade, is to be found only in canals in the neighbourhood of Manchester.

FIG. 147.—*Planorbis nautileus*, ENLARGED

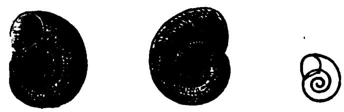


FIG. 148.—*Planorbis albus*, ENLARGED. BRISTLES REMOVED

Several species thrive well in the indoor aquarium, requiring no attention whatever if once supplied with suitable vegetation. In

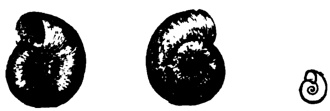


FIG. 149.—*Planorbis parvus*

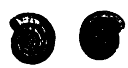


FIG. 150.—*Planorbis spirorbis*

illustration of this statement I may mention that I have now a considerable number of a few species (*Albus*, *Spirorbis*, *Vortex*,

FIG. 151.—*Planorbis vortex*

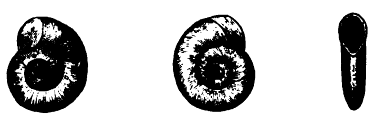


FIG. 152.—*Planorbis carinatus*

Complanatus, and *Corneus*) in a twenty-gallon aquarium, all the issue of a dozen or two introduced about three years ago, since which time the water has not been changed once. It should be known, however, that young univalves are not so successfully reared in the presence of fishes or carnivorous beetles. The latter, in fact,

FIG. 153.—*Planorbis complanatus*

FIG. 154.—*Planorbis corneus* (SEE ALSO PLATE II, FIG. 7)

will attack molluscs of all sizes, even biting through the thinner shells to obtain their prey; and the former, sticklebacks in particular, swallow the young as soon as they are liberated from the spawn. If it is desired to rear molluscs successfully from the ova, they should always be kept quite isolated; or, at any rate, perfectly free from all creatures of carnivorous tendencies.

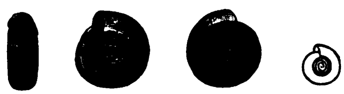


FIG. 155.—*Planorbis contortus*, ENLARGED

Much has been said about the value of water snails as scavengers, and for keeping the glass of an aquarium free from confervoid growths. As scavengers for bringing about the effectual removal of

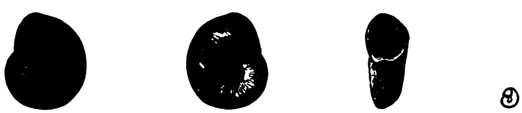


FIG. 156.—*Planorbis dilatatus*

decomposing organic matter, this statement is certainly true of *Planorbis* and the other *Limnæidæ*; but, as to the removal of confervoid growths on the glass, I have observed that they often crawl over such growths without making the least impression on them.

The following table deals with the principal distinguishing features of the species of the *Planorbis* genus:

Genus Planorbis

Shell spiral, flat. No operculum. Tentacles long and slender. Foot small, round or oval.

I. Shell convex above, flat below (quoit-shaped).

(*a*) Whorls four or five. Shell yellowish, polished.

1. White transverse plates, visible from exterior, in outer whorl. Umbilicus narrow, deep. Diameter one-fifth of an inch. *P. lineatus.*
2. Outer whorl wide, overlapping the next. Umbilicus small, shallow. Diameter one-fifth of an inch. *P. nitidus.*

(*b*) Whorls three. Dull brownish. Concavity above. Strongly marked transverse ridges on exterior. Umbilicus large. Diameter one-ninth of an inch.

3. *P. nautileus.*

II. Shell not quoit-shaped.

(*a*) Convex above; concave below. Umbilicus large. Mouth rounded.

4. Whorls five. Shell whitish, bristled. Diameter one-quarter of an inch. *P. albus.*
5. Whorls five or six. Shell brownish, polished. Concavity above. Diameter one-sixth of an inch. *P. parvus.*

(*b*) Shell flat.

A. Umbilicus deep.

6. Very convex below. Keeled. Whorls two. Mouth large and square. Diameter one-tenth of an inch. *P. dilatatus.*

B. Umbilicus shallow.

7. Slightly concave above or below. Slightly keeled. Whorls six. Mouth round. Diameter one-quarter of an inch. *P. spirorbis.*
8. Shell very flat. Keeled. Whorls seven or eight. Mouth rhomboid. Diameter three-eighths of an inch. *P. vortex.*
9. Slightly concave above; slightly convex below. Sharply keeled a little below the middle. Whorls five or six. Mouth oval. Diameter half an inch. *P. carinatus.*
10. Slightly concave above and below. Sharply keeled below. Whorls five or six; outer one larger than in

Carinatus. Mouth rhomboidal. Diameter three-quarters of an inch. *P. complanatus.*

(*c*) 11. Shell much swollen; reddish brown. Not keeled. Whorls five. Mouth semilunar; wide. Diameter three-quarters to one inch. *P. corneus.*

(*d*) 12. Shell flat above; very convex below. Whorls eight, much compressed laterally; outer one very large. Mouth crescentic; very narrow. Diameter one-fifth of an inch. *P. contortus.*

The above table should enable the beginner to identify most of his specimens of the *Planorbis* genus without trouble, but he should remember that he must always be prepared to meet with variations in form, size, and colour, which will at first cause him a little trouble.

In some cases (and these remarks apply not only to *Planorbis*, but also to a considerable number of species, both univalve and bivalve) the variations are themselves very variable in character, almost every possible gradation between the extreme and the normal being obtainable. But we sometimes meet with a striking abnormity of size, form, or colour which has become permanent in certain localities, thus producing what we call a *variety*. These permanent varieties have fixed names, which are appended to the ordinary names of the species to which they belong.

Thus the common species *Planorbis corneus*, which usually has a dark reddish-brown shell, is sometimes found perfectly white; and the variety, which, by the way, is not particularly rare, is known as *Planorbis corneus*, var. *albina.*

The study of variation in animal life is most interesting, and the collector of natural history objects should always be on the look-out for all kinds of abnormities, and compare those obtained very carefully with the normal specimens.

It would be impossible to deal with the varieties of the different species in the space at disposal. My aim is to supply the reader with a general outline of the structure and the broad principles of classification; but should he, after a few seasons' collecting, desire to make a special study of variation as exhibited in the shells of molluscs, he should refer to one of the manuals devoted especially to this branch of natural history.

Genus PHYSA.—The shells of this genus may be readily distinguished from the other spiral shells by the sinistral or left-handed turn. They differ from the *Paludinidæ* in having no operculum; and may be known at once from the genus *Limnæa* by the two long and slender tentacles, as well as by the extended mantle.

There are only two British species of this genus, if we exclude one (*P. acuta*) which has been introduced into this country somewhat recently, and which is to be found only in the Kew Botanical Gardens.

The larger of these (*P. hypnorum*) sometimes reaches three-quarters of an inch in length. The shell is an elongated oval, thin and polished, of a yellowish or reddish colour. The mouth is of an elongated oval form, pointed above, and a little more than half the length of the shell. This species is widely distributed, but is somewhat local.

FIG. 157.—*Physa hypnorum*

FIG. 158.—*Physa fontinalis*

The other species (*P. fontinalis*) is smaller, being generally less than half an inch in length. The shell is oval, thin, and transparent; and may be distinguished from *P. hypnorum* by the deeper suture, and also by the larger porportionate size of the last whorl, which forms more than three-fourths of the length of the shell.

This species is far more common and more widely distributed than the last. Both inhabit ditches and sluggish streams.

Genus LIMNÆA.—Most of the shells of this genus are remarkable for the number of their varieties, and the young collector must therefore be prepared to meet with many features not mentioned in the table which follows.

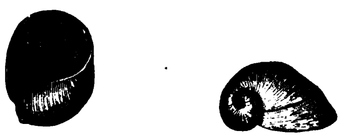


FIG. 159.—*Limnæa glutinosa*

FIG. 160.—*Limnæa peregra*

L. peregra, *stagnalis*, *palustris*, and *truncatula* are common in ponds, ditches, and sluggish streams in most parts. *L. glutinosa*, *auricularia*, and *glabra* are local, particularly the first and last mentioned. The other (*L. involuta*) has been taken only in a small lake in the Killarney district.

As already mentioned, these molluscs thrive and breed well in aquaria, and are, moreover, very useful for the removal of decomposing matter, which forms their principal food.

Fig. 161. *Limnæa auricularia*

Fig. 162. *Limnæa palustris*

Fig. 163. *Limnæa truncatula*

Fig. 164. *Limnæa glabra*

L. stagnalis (Plate II, fig. 8), being a very large species, is ornamental as well as useful; and the muscular movements of the foot are to be observed very easily as the creature creeps over the glass, or, in an inverted position, on the surface film of the water.

L. peregra feeds on decomposing animal as well as vegetable matter, and is therefore useful in reducing this dangerous source of contamination.

The following is a tabular arrangement of the members of this genus:

Genus Limnæa

Shell oval or conical; spiral; no operculum. Animal with two short triangular tentacles.

A. Shell oval, pale yellowish, thin, polished. Whorls three to five, the last forming the greater part of the shell. Spire small.

1. Shell globose. Whorls three or four. Mouth oval, about three-fourths the length of the shell. Length half an inch. *L. glutinosa.*
2. Whorls three or four. Spire sunken. Mouth large and pear-shaped. Length nearly half an inch. *L. involuta.*
3. Whorls five. Spire extended and sharp. Mouth oval, about two-thirds the length of the shell. Length half to seven-eighths of an inch. *L. peregra.*
4. Shell globose. Whorls four; last much expanded. Spire

very short; acute. Mouth much expanded, about five-sixths the length of the shell. Length three-quarters to one inch. *L. auricularia.*

B. Shell conical; tapering. Whorls five to eight. Spire long; acute.

5. Whorls six to eight; boldly striated. Mouth oval; rather over half the length of the shell. Length one and a half to two inches. *L. stagnalis.*
6. Shell thick, brown. Whorls six, separated by a fine white line. Mouth ovate; nearly half the length of the shell. Length one-third to three-quarters of an inch. *L. palustris.*
7. Whorls five or six. Suture very deep. Mouth ovate; less than half the length of the shell. Umbilicus distinct. Length half an inch. *L. truncatula.*
8. Shell an elongated cone. Whorls seven or eight. Mouth oval; narrow; less than one-third the length of the shell. Length three-quarters to one inch. *L. glabra.*

Genus ANCYLUS.—This is the last genus of the family *Limnæa.* It has only two British species, which are sometimes termed the freshwater limpets. Both are small, and one (*A. lacustris*) inhabits still or very sluggish waters, while the other (*A. fluviatilis*) is found only in streams.

A. lacustris is generally stationed on weeds, and its small conical shell fits so closely on the surface of the vegetation that it is liable

FIG. 165.—*Ancylus lacustris*, NATURAL SIZE AND ENLARGED

to be overlooked if not closely observed. The shell, too, is so very thin that it is often difficult to remove it without injury; for the animal holds on firmly by means of its broad oval foot. Those in search of this shell should carefully examine the surface of the leaves of flags and other aquatic or semi-aquatic plants, including the dead and decaying leaves which may be quite detached and lying on the bed of the water.

FIG. 166.—*Ancylus fluviatilis*

A. fluviatilis is larger than *Lacustris*, and the base of the shell is a broader oval. It may be found on weeds and on the surface of stones in rivers and streams.

Lacustris is local, but common in some parts. *Fluviatilis* is common in most parts except in the extreme north.

SEMI-AQUATIC MOLLUSCS

Those who devote their leisure hours to the observation of life in ponds and streams are sure to meet with many creatures of semi-aquatic habits—creatures which spend a portion of their existence only in the water, and the remainder either on the surface or in the immediate neighbourhood; and others which are never aquatic in the strictest sense of the term, but which show their partiality for the water by making their homes in the damp soil of marshes and the banks of ponds, ditches, and streams, or on the semi-aquatic plants that derive their food from ground saturated with water.

Such creatures may well be considered within the legitimate province of a water-searcher's labours, and among them we have to place a certain group of 'snails' that are more generally classed with terrestrial species, but which are always found near water, either in marshes, or on plants that grow on the banks of ditches, streams, and ponds.

The group referred to (genus *Succinea*) belongs to the family *Helicidæ*, which contains the common snail (*Helix aspersa*) that was, as a matter of convenience, chosen for our examination as a type of the *Gasteropods*.

It will hardly be necessary to recall the various points in the anatomy of this type, but it may be observed here that the chief feature by which these semi-aquatic snails are to be distinguished from their truly aquatic relatives is the presence of four tentacles, cylindrical in form, the dorsal and longer pair bearing the eyes at their summit.

FIG. 167.—*Succinea putris*

In the genus *Succinea* the shell is spiral, of an oval or oblong form, and very thin. The spire is generally very short, and the mouth, which is very large, has no operculum. The tentacles are much shorter in proportion than in *Helix*.

Perhaps the commonest species is *S. putris*, which measures from a half to nearly three-quarters of an inch in length. The shell is ovate in form, thin and transparent, polished, and of a pale amber colour. There are three or four whorls, and the mouth is quite two-thirds the total length of the shell. This species may be found on flags and other semi-aquatic plants in most parts.

Another mollusc—*S. virescens*—is sometimes regarded as a variety of *S. putris*, and not a distinct species. It is smaller than *S. putris*, however, seldom reaching half an inch in length, and is of a delicate greenish colour. It occurs in some districts round London, and in a few other isolated localities.

FIG. 168.—*Succinea elegans*

A third species—*S. elegans*—is very common in many parts, but far more local than *S. putris*. Its shell is not so transparent as the preceding. It is also narrower, and the spire is extended and more acute. It reaches about half an inch in length. Another one, *S. Pfeifferi*, is of about the same size, but the shell, which is transparent, is of a deep amber or reddish tint; and the spire, which is shorter, is swollen. This is also a local species, but common in the districts where it exists.

To the above may be added a much rarer species, *S. oblonga*, which seems to have a partiality for salt, as it inhabits only the banks of ditches close to the sea. It is a quarter of an inch long, of a pale yellowish colour, and the mouth is half the length of the shell. Although rare, it is very widely distributed.

CHAPTER IX

FRESHWATER CRUSTACEANS AND SPIDERS

WE have now to deal with that large sub-kingdom of animal life called the *Arthropoda*, which includes a vast number of creatures that are distinguished by a hardened protective skin made up of a number of segments, each bearing a pair of appendages.

Although there are considerable variations in the form and size of the different segments, even in the same animal, yet all are constructed on the same plan. Each consists of an upper or dorsal plate, usually convex above, and a lower or ventral plate, also generally convex on the outer side; and the appendages arising from the segment are attached at or near the points where these two plates meet.

The appendages of *Arthropods* also consist of a number of jointed parts, and are all surrounded by a hardened skin similar to that which covers the body. Three or more pairs of these appendages are used for purposes of locomotion either on land or in water, and the others are modified for the performance of certain special functions, such as prehension, the crushing or sucking of food, or as organs of sensation.

We shall observe that the Arthropods are as a rule much more highly developed than any of the creatures already described, though in many respects they resemble the worms. They have generally a very complicated digestive system; and, unlike the simply formed soft-bodied animals, have special well-developed organs of respiration by means of which air can be obtained either from water or direct from the atmosphere. The nervous system consists of a chain of little masses of nerve substance (*ganglia*) arranged longitudinally along the lower part of the body, all connected by nerve cords, and giving off radiating nerves to the various parts of the body.

Hitherto we have been considering forms of animal life which are not generally well known except to students of natural history. They are either too small to attract the attention of ordinary observers, or they are too far down the scale of life to be worthy of notice; but the *Arthropoda* contain a large number of creatures that are not only well known to every one, but even admired more or less by all, either on account of the beautiful colours they display, or their interesting ways, the high degree of intelligence they exhibit, or because they benefit mankind by supplying them with food or some other useful commodity.

The sub-kingdom is divided into four classes: *Crustacea*, *Arachnoidea*, *Myriapoda*, and *Insecta*.

The first of these includes Crabs, Lobsters, Crayfishes, Shrimps, Prawns, and other smaller and less familiar animals. The *Arachnoidea* includes Spiders, Mites, and Scorpions. The *Myriapoda* embraces Centipedes and Millepedes; and the *Insecta* or Insects need not here be defined.

The third of these classes will not engage our attention at all. The present chapter is to be devoted to the aquatic Crustaceans and Spiders; and the Insects are of sufficient interest to claim a somewhat lengthy chapter to themselves.

Crustaceans

The largest of our freshwater Crustaceans is the River Crayfish (*Astacus fluviatilis*), which is very common in many of our rivers, especially those in chalky and limestone districts, but either scarce or unknown in the streams which flow over granite and other hard rocks containing little lime.

Crayfishes can generally be obtained without much difficulty from dealers in aquarium pets; but if the reader is in a position to search out the creatures in their haunts he should capture his own specimens rather than apply to a dealer. And this remark applies equally well to all the various kinds of aquatic animals that are kept in captivity. Aquarium keepers often rely solely on this method of stocking their vessels; but how much better is it to gather one's specimens oneself, not only because we naturally take more pleasure in studying the creatures taken with our own hands than those bought at a price, or because the mere employment calls us out and gives us exercise in the pure country air, but mainly because we are thereby furnished with an opportunity of watching the creatures in their native element, and of studying their habits and habitats.

No particular apparatus is needed by the crayfish hunter. The animals are to be caught without bait, and may be taken home alive without a drain of water.

During the winter months crayfishes spend much of their time in holes in the banks of rivers, and they are then so inactive that they are easily dug out with a spade; but this is the least interesting of all the modes of capture—at least to the naturalist.

In France, where crayfishes are in great request as an article of food, several very different modes of capture are practised. Sometimes baskets containing meat or dead frogs are let down into the water, and then lifted out again quickly either when crayfish have actually been seen to enter or when it is supposed that they have done so. During the heat of the day they remain in their burrows in the banks, or seek shelter from the sun's rays under stones in shallow water; but in the evening twilight, and also after dark, they roam about in search of food, and can then be taken in a dredge. When this method is employed a strong light is sometimes thrown on the water, not with the object of rendering the crayfishes visible, but because the light attracts them just as it does certain insects.

The above methods are perhaps more suitable for the professional fisherman than for the aquarium naturalist. To the latter there is nothing better than searching for the crayfishes in their hiding places in broad daylight. They lie at the openings of their nooks, generally with nothing protruding save their long antennæ and their claws. Here they are always on the alert both for their food and for their enemies. On the approach of the latter the crayfish suddenly darts backward into its hole, never turning, but always keeping its face to the foe.

The best way is to proceed slowly up the stream, wading in water close to the bank, and watching for the slender antennæ. As a rule their holes are too small to allow the hand to pass, but the crayfish can usually be pulled out easily by means of its antennæ.

Of course the captor must not expect to engage in much of this kind of sport without an occasional nip of the crayfish's claws; but although the power of these limbs is considerable, and the first nip or two is rather startling, one soon takes it all as a matter of course.

I have always found crayfishes thrive best in a large shallow tank or trough, with large stones loosely piled in such a manner as to provide numerous hiding places. The water should either be always running, or set flowing at frequent intervals; and the waste pipe should be at the level of the topmost stones.

As to feeding, crayfishes will eat anything, either vegetable or animal, that satisfies our own appetites. They will devour many kinds of pondweeds, and aquatic snails and other animals, the shells of the former being devoured as well as the soft structures within them. They also partake readily of carrot and turnip and the stalks of cabbage—in short, anything ; but care should be taken that no large excess of decomposable matter be allowed to remain in the water, or it will soon become putrid and poisonous.

Now let us watch our captive crayfishes in order to acquaint ourselves with their habits.

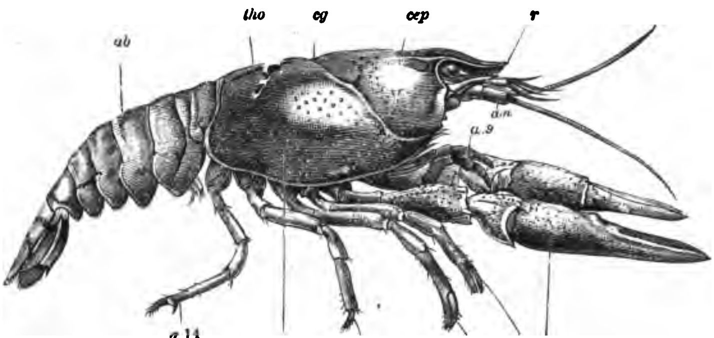


Fig. 169.—The Crayfish (*Astacus fluviatilis*)

r, rostrum or beak ; *cep*, cephale or head : *tho*, thorax ; *cg*. cervical groove, between head and thorax ; *ab*, abdomen ; *br*, portion of shell covering the gills ; *an*, antennæ ; *a* 9–14, thoracic appendages

During the greater part of the day they remain hidden among the piled stones provided for them, with their heads and foremost appendages just visible. If we make a sudden approach towards them, or threaten them by thrusting a stick before their holes, they suddenly dart backward under cover ; and if we then intrude within their homes they will not hesitate to grasp the intruding object with their large claws by way of defence.

In the evening they come out to feed ; and if we now approach so cautiously as not to disturb them we may watch their movements with ease. Their long antennæ are now held forward, and kept in motion as if to try the way. In fact these organs are undoubtedly very sensitive, and serve the purpose of feelers like the antennæ of insects and the whiskers of the rat and other mammals.

If now we threaten or alarm them, we shall be able to see by wnat means the crayfishes are enabled to dart backward. As they climb about over the stones we observe that the powerful jointed tail is extended, and that they progress principally by means of their five pairs of legs. When, however, we alarm the creatures they suddenly double their powerful tails forward under their bodies,

FIG. 170.—THE CRAYFISH, UPPER SIDE

at the same time spreading out their flat and fringed terminal appendages to their full extent, and thus retreat with a rapid series of jerks till they reach the entrance of their home, into which they then shuffle themselves backward, never for a moment turning their back on the enemy.

The crayfish will also demonstrate the power of its muscular abdomen in an amusing manner if we lift it out of the water, grasping it between the finger and thumb at the thickest part of the body. Not knowing that its powerful organ of retreat loses its efficiency when struck against the air, it flaps it vigorously, striking the under side of its abdomen with considerable force at each movement.

With the creature still in our hand we will proceed to note its external form and structure. Its skin is tough, and is hardened by

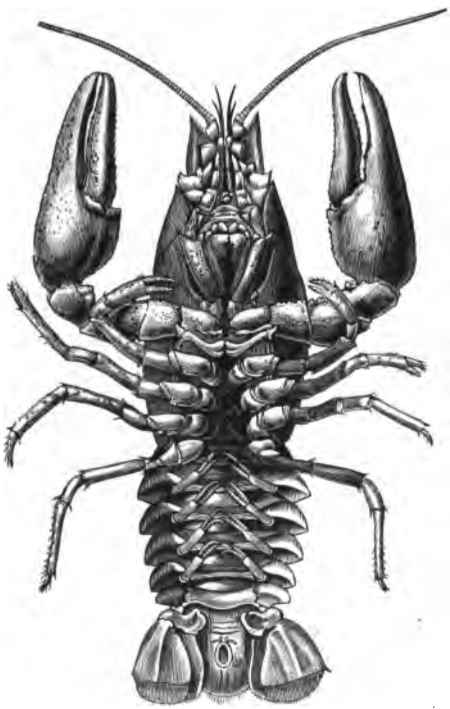


FIG. 171.—THE CRAYFISH, UNDER SIDE

a deposit of carbonate of lime except where flexibility is required, as between the moveable segments of the hinder portion of the body; and this same skin is reflected inwards at the beginning and end of the food passage, forming an almost complete lining for the whole digestive tube.

The body is seen to consist of two main portions—a large one in front, consisting apparently of only one segment, and a hinder portion composed of six segments moveable one on the other.

The large anterior part is the head and thorax combined, and a depression on the upper surface of the great shield (the *carapace*) which covers it marks the division between these two parts. The whole, however, is not looked upon as a single segment, but is regarded as consisting of fourteen segments all fused together; for not only has it fourteen pairs of appendages, but on the under side we may observe traces of a division as just suggested.

In order to get an idea of the general character of each segment or *somite*, we will examine one of the moveable divisions of the abdomen. It has an arched portion above, and a narrower and slightly convex bar below; and the former is prolonged downwards beyond its junction with the latter. Then close to the point where the two meet, on either side, an appendage is situated.

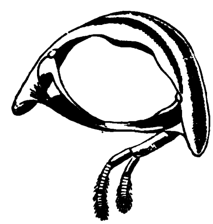


FIG. 172. – THE FOURTH SEGMENT OF THE ABDOMEN OF THE CRAYFISH, WITH APPENDAGE ON ONE SIDE

The appendage in this instance is called a swimmeret, and is made up of a single basal joint, at the end of which are jointed an inner and an outer part, both of which consist of several joints and are fringed with hair.

Each of the abdominal segments has its pair of appendages, but in some cases they are very imperfectly developed; and those of the last one are modified to form the broad and flattened tail, the use of which we have already observed.

If we bend the abdomen under the body we notice that the front portion of the upper arch of each segment is very smooth; and on extending the body again, we see that this smooth portion slides without friction beneath the hinder part of the segment immediately in front of it.

It will be interesting now to look at the various appendages of the large anterior portion of the body, which, we have learnt, forms the head and thorax, and which is consequently termed the *cephalothorax*.

The first of these are the eyestalks—two short cylindrical rods, each of two joints, which carry the eyes at their tips.

The eye itself is a very wonderful structure. for it consists of a number of little transparent pyramids, four- or six-sided, all radiating from a point at the head of the stalk, and their bases forming the outer convex surface of the eye.

Each pyramid is divided from its neighbours by a layer of cells containing a very dark colouring matter; and the outer membrane of the eye, which is a modified continuation of the skin of the whole body, consists of a number of little facets or lenses, one forming the base of each pyramid.

Thus the eye of the crayfish is compound. Every one of the little facets has the power of converging the rays of light that pass through it, and of forming an image within its pyramid; and confusion of the different images formed by the various facets is prevented by the opaque pigment that lies between the pyramids. Further, at the apex of each pyramid there is a nerve fibre to receive the light vibrations and transmit them to the large ganglia of the head.

Of course we are not able to determine the nature of the crayfish's vision, but only those rays which strike the convex surface perpendicularly can penetrate the eye and reach the optic fibres, and therefore each little compartment of the compound organ forms its own image of the object that lies exactly opposite its central axis.

Between and above the eyes there is a sharp projection of the hardened skin, forming what is known as the beak or *rostrum*, and beneath this there is a pair of *antennules* or short antennæ. These are followed by a pair of long *antennæ*, and both these and the smaller ones are composed of a number of little segments.

And now, if we examine the under side of the head, we see several pairs of appendages placed more or less closely round the mouth. Taking them in their proper order, from before backwards, the first of these is a pair of *mandibles* or jaws, strong and hard, one on each side of the mouth. They move horizontally, and are toothed like a saw on their inner edges. Then follow two pairs of *maxillæ*, the second of which has a large and thin plate that lies hidden beneath the overhanging shield at the side of the head, and concerning which we shall have more to say presently.

The twelve appendages above named are all regarded as belonging to the head of the crayfish, and the head is looked upon as consisting of six segments fused into one. Then follow the segments of the thorax, eight in number, with a corresponding number of pairs of appendages. The first three of the latter are termed *maxillipedes* or foot-jaws, because they are used in conveying the food from the large claws or pincers to the mouth.

The other five pairs of thoracic appendages are the long walking legs, the first of which bears the powerful claws just mentioned, and the second and third also exhibit rudiments of a pair of grasping organs.

The remaining appendages are the swimmerets of the abdomen, one of which we have already observed. These little organs are used as paddles, and assist the crayfish in moving through the water; but the creature spends its time chiefly on the bottom, and the five pairs of legs are by far the most useful organs of locomotion.

When examining one of the abdominal segments, we observed that the dorsal plate extended downward on each side below its junction with the ventral plate. Now it will be seen that the same arrangement obtains in the thorax, where a cavity is formed along each side of the body, between the prolonged dorsal plate and the side of the thorax, which is enclosed by the bases of the walking legs.

Within this cavity are the plumelike gills, attached in part to membranes between the limbs and the body wall, and in part to the bases of the limbs themselves.

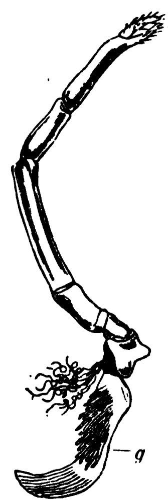


FIG. 173.—WALKING APPENDAGE OF CRAYFISH WITH GILL (*g*) ATTACHED

Water can pass freely through this chamber, thus bathing the gills, and promoting the exchange of gases that constitute the process of respiration. And since some of the gills are attached to the bases of the limbs, every movement of the latter must assist the breathing by promoting the circulation of water in the gill chamber. Further, the thin broad plate of the second maxilla, to which we have already referred as lying within this chamber, is always moving backwards and forwards, bailing the water out at the front opening at every forward movement.

This movement can be easily traced in a living crayfish as you hold it in your hand, the outer wall of the gill chamber being generally sufficiently transparent to enable the movements of this organ to be distinctly seen.

Although the crayfish is a gill-breathing animal, it can live for a long time out of water, provided the atmosphere around it is cool and moist; but the gills become absolutely useless when dry.

The internal anatomy of the crayfish reveals many points of interest even to a beginner, and much may be made out by the aid of simple dissections such as could be accomplished by any one. The specimen chosen for dissection should be fresh, and if it is found to be necessary to kill one for the purpose, this may be done expeditiously by giving it a momentary immersion in hot water; or a specimen that has been preserved in spirit will answer very well.

In any case the dead animal should be pinned out in a shallow trough of water, the pins being secured in a layer of wax that has been previously melted and run into the trough, or in a sheet of cork weighted with lead. Such an arrangement may seem unnecessary to a young anatomist, but he will soon learn to appreciate the value of this method of conducting a dissection if he will only compare his results obtained both with and without the use of the trough. With its use the soft parts are well displayed, and an occasional change of water as it becomes turbid will keep his work beautifully clean.

The top shell of the crayfish may be removed by carefully cutting it away with a finely pointed pair of scissors, care being taken not to allow the instrument to damage the internal organs.

By this simple process we expose the whole of the digestive tube, including the large stomach in the thorax, and the straight intestinal tube running through the abdomen.

The stomach consists of two distinct parts—a large chamber in front, and a smaller one behind it; and if the organ be opened carefully it will be noticed that parts of it are of a hard bony structure. It contains, in fact, several little *ossicles* which are actuated by muscles, and thus constitute a very effective apparatus for the mastication of food.

The same dissection also reveals the heart, which is a five-sided organ, situated about the middle of the thorax; the digestive gland, a yellow pulpy organ which prepares a digestive fluid; also a pair of green glands, lying beneath the front of the stomach, which separate waste products from the blood, and correspond with the kidneys in vertebrate animals.

In addition to these structures we observe the organs of reproduction, and the mass of white flesh which forms the powerful muscles of the abdomen.

And now we must note the position of the nervous system, which is very different from that of the vertebrates. In the latter the central or chief part of the nervous system lies down the middle of the back, near the dorsal surface, and is usually protected by a bony tube; but in *Crustaceans* we find it lying along the middle of

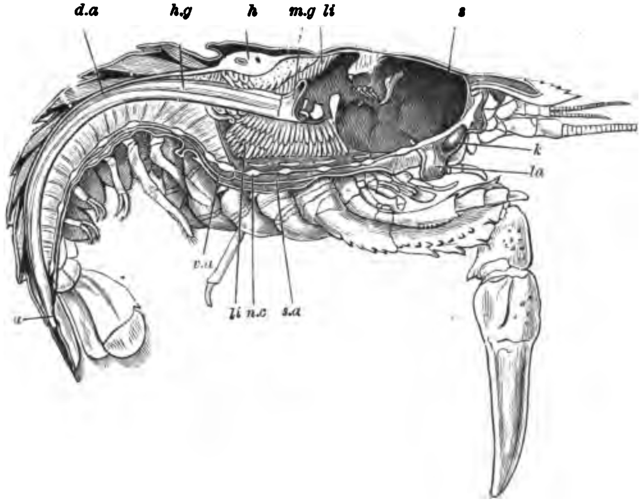


FIG. 174.—LONGITUDINAL SECTION OF THE CRAYFISH

a, anus; *d.a*, dorsal artery; *h*, heart; *h.g*, intestine or hind gut; *k*, kidney; *l.a*, labrum or lip; *li*, liver; *m.g*, mid gut; *n.c*, nerve chain; *s*, stomach; *s.a*, sternal artery; *v.a*, ventral artery

the ventral surface, and occupying the same cavity as the organs of digestion and circulation. In order to display it we must remove all the latter, and very carefully pick away the muscles at the bases of the appendages and the mass of flesh that fills the abdomen. This being done, we see the chain of nerve ganglia and the delicate white nerve threads which unite them.

We have previously noted the position of the gills. These organs are necessarily richly supplied with blood sent to them for aëration.

The aërated blood is then conveyed to the heart by means of several vessels, and the contraction of the heart propels it to all parts of the body. The circulation continues for a time in a crayfish that has been killed, and if it is opened shortly after it is dead the contraction of the heart may be observed.

The organ which serves the purpose of an ear is situated in the first joint of the small antennæ. It is a simple little pouch containing grains of sand, and is surrounded with minute branches of the auditory nerve.

The antennules are also the seat of the sense of smell; at least, it is in these appendages that we meet with little organs that are supposed to have an olfactory function. There are many other points of interest which the student may observe in the structure of the crayfish.

Like most other *Crustaceans*, crayfishes have the remarkable power of reproducing lost limbs. It is a very common thing to meet with some that have one or more limbs smaller than the corresponding ones of the opposite side. These are new limbs that are growing in the place of some that have been lost either in combat or during struggles to escape from an enemy.

An injured limb is always cast off at a joint above the seat of injury, and, in the case of the clawed legs, usually at the narrowest joint. Thus the injury is transferred to a point where the soft structures are constricted, so that there is not only less danger of the animal bleeding to death, but the soft parts close over and heal much more rapidly. The new limb formed eventually becomes as large, or nearly so, as the original.

In the fall of the year the body of the female crayfish contains a large number of dark-coloured eggs, which, when laid, are covered with a gelatinous substance; and this substance not only causes the eggs to adhere to the swimmerets of the parent, but soon hardens and forms a number of little stalks by which they remain permanently attached.

The young are hatched early in the following summer. They are then little semi-transparent greyish creatures, rather less than a quarter of an inch in length, and still cling by means of their claws to the gelatinous matter that formerly supported the eggs.

Soon, however, they detach themselves from the parent, but remain so near her that they can readily fly to her for protection in times of danger. After a time, however, they stray away and shift for themselves.

At first they grow very rapidly, and attain a length of about an inch and a half during the first year, but after that the growth is less rapid, being rather less than an inch a year till the time that they reach maturity at the age of four or five years.

At this period they are nearly five inches in length, but the males are usually a little longer than the females, and the bodies of the latter are considerably broader.

The growth of the crayfish is not regular, but takes place rather rapidly at certain short intervals following the moults, or casting of the skin; and these intervals are necessarily shorter during the more rapid development of the young, occurring about three times during the course of the first year, and about once a year after. Although we use the term 'casting of the skin,' it must be remembered that the skin is not entirely shed, but only the outer and hardened layer or epidermis.

When the time arrives for the moult the creature struggles vigorously within its case, every limb and even every appendage taking part in the action. Thus each part is loosened within its shell, even to the eyestalks and the slender antennæ, and is gradually pulled towards the middle of the body. Then the membrane between the thorax and the abdomen breaks away on the upper side, the hardened integument of the limbs is split, and the creature struggles till it has completely freed itself from its old coat, which retains its perfect form after having been vacated.

Now, though its body is firm, the newly exposed skin is soft and yielding, and remains so for a few days, during which time the creature grows rapidly. Then the new skin gradually hardens by the deposition of carbonate of lime, and the growth is arrested till the time of the following moult.

It not unfrequently happens that one or more of the limbs break off during the creature's struggles to release itself from its old coat, but, as we have already learnt, these limbs are replaced by new growths. Further, the moulting periods are times of great danger, for not only is the crayfish liable to be injured by enemies which could do it no harm while it was covered by a calcareous armour, but it sometimes succumbs from the effects of the violent struggles necessary to set itself free. It is interesting to note, too, that the hardened lining of parts of the digestive tube is also cast off at the same time as the outer skin; but this is gradually dissolved in the creature's stomach, and undoubtedly helps in the building up of the new armour.

The Freshwater Shrimp (*Gammarus pulex*) is another very common crustacean, to be found in abundance in almost every stream and ditch. It is far more lively than the crayfish, and swims about very actively with a jerky motion. As a rule it keeps near the bottom, or rests on the stalks of submerged leaves, and feeds on all kinds of decomposing organic matter, both animal and vegetable.

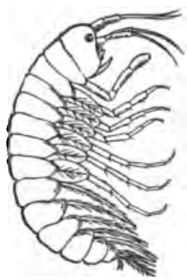


Fig. 175. The Freshwater Shrimp

Like the carrion beetles on land, it will swarm round the decomposing body of a dead animal, devouring it greedily; and when such feasts are not in its way, it will turn its attention to decaying vegetation. Hence, like all carrion feeders, it performs a very useful work in disposing of those matters which would otherwise become putrid and poisonous, and pollute either the water or the air.

It thrives well in the aquarium, especially when that aquarium is so badly managed as to allow the food it requires to accumulate; but it cannot be kept in company with carnivorous insects and fishes, many of which feed on it. The River Bullhead is very partial to it, and the little Stickleback, though it does not seem to be able to swallow a full-grown *Gammarus*, will nevertheless chase it about in a most amusing manner.

The Freshwater Shrimp belongs to the section of Crustaceans called *Edriophthalmata* or *Sessile-eyed Crustaceans*, its eyes, though prominent, not being mounted on movable stalks like those of the Crayfish. The section is also spoken of as the *Tetradecapoda* or *Fourteen-footed Crustaceans*, while the Crayfish belongs to the *Decapoda* or *Ten-footed Crustaceans*.

Its body is greatly curved, and its limbs are turned in all directions, and are used for walking as well as for swimming.

It breathes by means of air sacs, which are surrounded by blood-vessels and connected with some of the limbs.

Other Freshwater Crustaceans, belonging to the same order, are parasites, living on the flesh of fishes and other aquatic animals, to the outer surface of which they attach themselves.

There is another division of the Crustacea termed *Isopods*—a word which signifies ‘equal-footed,’ but yet the legs are not always equal in size, nor are they all of the same build. This division includes the well-known wood-lice that hide under stones and in rotting trees. It also includes aquatic creatures, of a very similar appearance, that belong to the family *Asellidæ*.

One of them, *Asellus aquaticus*, is exceedingly common in most of our ponds, where it may be found creeping on the bottom or on submerged weeds. It is about half an inch in length, but the male is larger than the female; and it is popularly known as the Water-hog Louse.

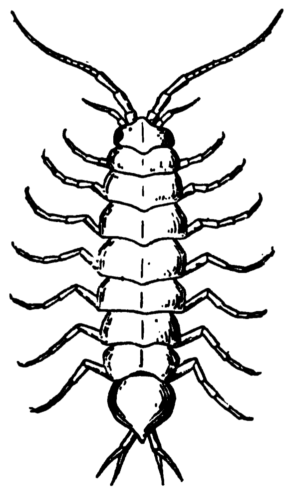


FIG. 176.—*Asellus aquaticus*

The body is rather flat, and is made up of nine segments, the first of which is the head, the last one the abdomen, while the intermediate seven segments are all regarded as belonging to the thorax. The segmentation too is very distinct, the body being very deeply divided at the joints. It has long appendages at the tip of the abdomen, and the thoracic segments bear walking limbs.

The Water-hog Louse is perfectly harmless in the aquarium, and since it feeds almost entirely on decomposing organic matter it may even prove more or less useful as a scavenger. Like the Freshwater Shrimp, its eyes, which are compound, are not mounted on moveable stalks.

The water from almost every pond or ditch contains little crustaceans, some so small as to be almost invisible to the naked eye, swimming about actively with a very jerky motion. These are commonly called Water Fleas, but they include a considerable variety of creatures which are not closely related to the true fleas.

Some of them belong to the genus *Daphnia*, which includes about seven species. In these the carapace is of such a form as to resemble the shell of a bivalve mollusc. It is also so transparent that the whole of the internal organs can be seen most distinctly within it. The abdomen is rudimentary, and is capable of being withdrawn within the carapace.

The compound eyes are represented by a single spherical structure, the cornea of which is composed of many facets or lenses. The jaws are strong and armed with spines, and the front of the carapace terminates in a prominent beak.

The antennæ are very large and powerful, and form the chief means of locomotion; but the antennules are small and rudimentary

Fig. 177.—Water Flea (*Daphnia pulex*), magnified

Water Fleas belong to the division *Branchiopoda* or Gill-footed Crustaceans, so called because the breathing organs are attached to the limbs

They are most active when the sun is low, both in the morning and the evening, when they are continuously jerking about among the water weeds or playing just under the surface; but during the heat of the day they settle on the muddy bottom, often in such vast numbers as to give a decided colour to the water.

The male is much smaller than the female, and is comparatively rare. In fact it is never to be seen at all except at certain seasons.

After the eggs are laid they are retained by the female in a space between the side of the carapace and the body, and there they are held until the young are perfectly formed.

Pond water also abounds with little pear-shaped creatures belonging to the genus *Cyclops*. These are often called Water Fleas, for they swim about with a series of sudden jerks much in the same way as the *Daphnia*, and they also resemble the latter in many respects.

The body of Cyclops is flattened on the ventral and convex on the dorsal side. The head and thorax form the larger part of the body, and the carapace which covers this part terminates in front in a curved rostrum.

The antennules are large and strong, and form the chief means of locomotion, being used after the manner of oars; the antennæ are much shorter than these.

The eyes are both fused into one dark mass of a globular form in the middle of the forehead, a feature which has suggested a resemblance to the one-eyed giants of Greek mythology. Hence the animals in question are termed *Cyclops*.

The mouth is provided with a pair of mandibles, and the foremost appendages of the thorax are two pairs of large and strong foot-jaws, while the others are paddle-like organs which assist in the movements of the animal, and are used like oars.

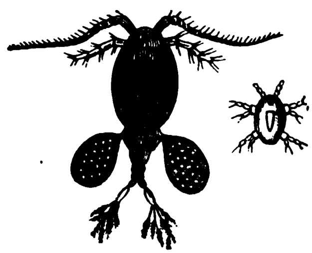


Fig. 178.—*Cyclops quadricornis*, female carrying the egg sacs. Also the Larva, magnified

Fig. 179.—A *Cyclops* viewed from the side

Behind the cephalo-thorax there are four moveable segments, behind which the abdomen is enlarged; and then follow other segments which taper off towards the extremity.

Attached to the enlarged portion of the body of the female there is a pair of large pear-shaped egg sacs, in which the eggs are carried till the young are hatched. At first these young are very unlike the adult, but they undergo a series of metamorphoses like the larvæ of insects.

The male is much smaller than the female.

Aquatic Spiders

The spiders possess certain characteristics in common with crustaceans. Like them their bodies are made up of two distinct parts, the foremost of which is the combined head and thorax, and the other the abdomen; but the latter is generally united to the former by means of a very slender stalklike waist, and is not segmented like the corresponding part of the crayfish, nor does it bear any limbs.

As we commonly hear spiders spoken of as insects, it may be well here, as we enumerate the chief points in their general structure, to call attention to certain important differences between the *Arachnidæ* and the *Insecta*, which, as we have already seen, belong to two distinct classes of the *Arthropoda*.

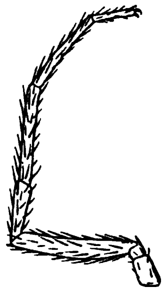


FIG. 180. — LEG OF A SPIDER

In the latter, it will be remembered, the head is quite distinct from the thorax, and often united to it by an exceedingly narrow neck.

The abdomen of spiders is very variable in form, being globular, egg-shaped, cylindrical, or even triangular.

The walking appendages are eight in number (in insects always six), and are all attached to the thorax. They are built up on the same plan as the legs of insects, each leg consisting of seven parts. The first of these is the hip or *coxa*, followed by the *trochanter* and a robust *femur* or thigh. Then come the *tibia* or shank, represented by two joints, and the *tarsus* or foot which terminates in powerful claws.

Unlike both crustaceans and insects, spiders have simple eyes, and these, usually eight in number, are situated on the front of the upper surface of the head. The arrangement of these organs is very variable, but they are commonly placed in two transverse rows.

Above the mouth there is a pair of powerful forceps or *falces*, by means of which the spider seizes and holds its prey. Each of these consists of two joints, the first of which is stout and grooved along the inner side. The second is slender, and terminates in a sharp point. It is also traversed by a canal which opens at the tip, and communicates with a poison-secreting gland in the first joint. When the falces are not in use the second joint folds into the groove of the first, just as the blade of a clasp-knife folds in the handle. It will thus be seen that the falces are merely organs of prehension, with the power of poisoning the prey, and are not concerned with feeding in any way, as are organs of a similar build in certain aquatic insects; yet they are often spoken of as mandibles.

Below the falces is a pair of *maxillæ* or lower jaws, which are composed of five joints, and are developed to such an extent as to resemble a pair of legs, for which they may be easily mistaken by those not acquainted with the structure of spiders. The organs in the mouth are not conspicuous, being enveloped in a sheath, as we shall presently observe is the case with many insects.

The spinning organs, or *spinnerets*, constitute one of the most interesting features of spiders. These are situated at or just under the tip of the abdomen, and are either two, four, six, or eight in number, and mounted on wartlike prominences.

Each spinneret is perforated with a number of minute holes, from which issue as many delicate threads of a viscid substance, and these all unite to form a single thread, which hardens into a kind of silk almost immediately on exposure to air. The fluid itself is prepared by the silk-glands, which lie in the abdomen, and communicate with the spinnerets by means of fine ducts.

We have now to note one or two of the chief features in the internal anatomy of the spider, and first we will briefly examine its breathing apparatus. In the front portion of the abdomen there are two or four air sacs which serve the purpose of the lungs of higher animals, since the blood circulating round them is aërated by the absorption of air obtained direct from the atmosphere. The air is admitted into the air sacs through slitlike apertures which may be seen on the under side of the front part of the abdomen.

In addition to these organs the spider possesses a system of tracheæ or air tubes, which communicate with the exterior by two openings either near the air sacs or at the tip of the abdomen.

The digestive tube of the spider is short, and the stomach, which is a hollow ringlike organ, gives off a number of radiating blind tubes.

The blood is colourless, and is propelled by a four-chambered heart situated in the abdomen. The chambers are arranged longitudinally in a single line, and the blood is received behind, and then propelled forwards into the arteries which carry the fluid to all parts.

It will be remembered that some of the crustaceans and most insects undergo metamorphoses, so that the young are very different from the adults in form. This is not the case with spiders, the young, just having issued from the egg, being of the same form and build as the adult. Further, unlike insects, but like some of the crustaceans, spiders continue to moult after having reached the adult stage.

Spiders are usually divided into two main groups, the Six-eyed (*Senoculina*) and the Eight-eyed (*Octonoculina*). Most of the

British species and all our aquatic ones belong to the latter, of which there are several families.

The common Garden Spider belongs to the family *Epeiridæ*, in which the eyes are arranged with a square of four eyes in the middle of the forehead and two on each side. The legs are long and stout, the third pair being shorter than all the others. The abdomen is large and generally oval or globular, and there are three pairs of spinnerets.

All the *Epeiridæ* construct snares to entrap their prey, and most of them are of terrestrial habits; but a few species are likely to come in the way of the pond-hunter, as they spin their webs among aquatic plants, and prey almost entirely on aquatic insects. None, however, actually live in water.

The pet spider of the student of pond life is undoubtedly the Water Spider (*Argyroneta aquatica*), and the habits of this creature are so interesting that it has attracted a great deal of attention for a long time. It belongs to the family *Drassidæ*, the members of which are distinguished by an oval abdomen, and eyes arranged in two curves which are convex towards the front of the head.

Although an air breather, obtaining its air direct from the atmosphere, yet it spends the greater part of its existence beneath the surface of the water, and is very commonly to be found among the contents of the pond-hunter's net. Still it seems quite at home when on land, and it often leaves the water to search for prey among the vegetation of the banks. In this case, however, it seldom devours its captives on land, but carries them away to its aquatic home, where it will even store up food for a future day.

Its abdomen is covered with a very fine downy hair which the water cannot penetrate; hence when it dives or walks down the stems of aquatic plants it is covered with a layer of air which gives it the appearance of a moving globule of silver.

This air is of course necessary for its respiration, but is not sufficient to satisfy its wants for any great length of time; therefore the creature must either make frequent visits to the surface to renew its supply, or it must in some way or other lay up a store of air beneath the surface.

Now, both these alternatives are resorted to by *Argyroneta* at different times, and its method of conducting the latter is exceedingly interesting. It constructs a silken cell like an inverted cup, and moors it by threads of the same material to the stems and leaves of submerged plants. Having finished this portion of its work, it makes several visits to the surface, each time returning to its cell with a fresh supply of air entangled among the hair of its

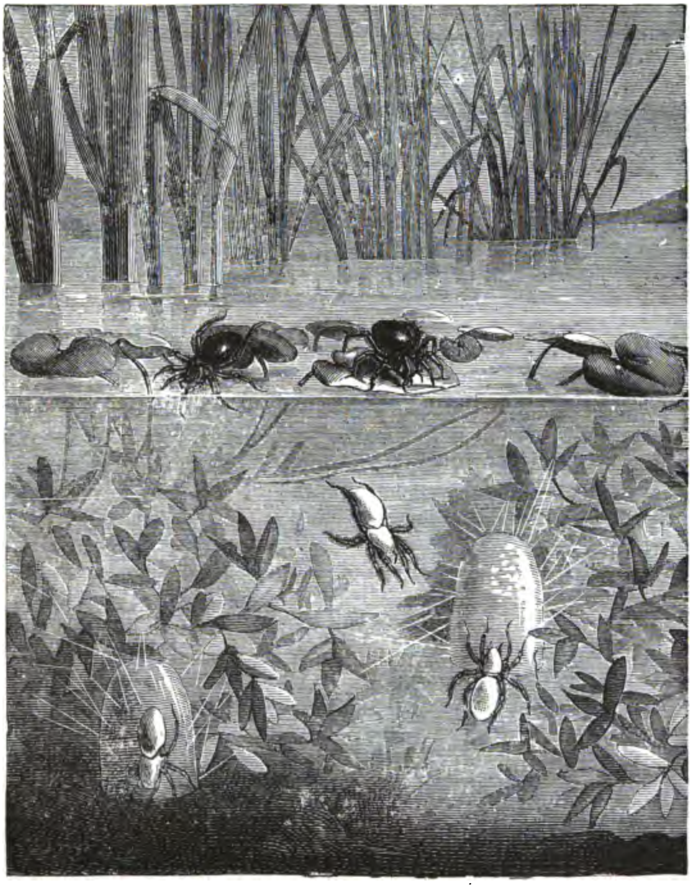


FIG. 181.—*Argyroneta aquatica* AND ITS NEST

abdomen, and allowing a portion of this air to rise into its inverted silken cup. In this way it stores up sufficient air to enable it to rest below the surface for some time without the necessity of paying further visits to the top.

It further utilises its little home as a nursery for its young, for the female places within it the little silken cocoons in which she encloses her eggs, and these she watches closely till the young ones are hatched. During the winter months it is far less active; in fact it shuts itself up within the cell when the cold weather arrives.

Argyroneta is about half an inch in length, but the male is larger than the female. I strongly advise the reader to capture a few in order that he may watch their interesting proceedings; but they must have plenty of room, a good supply of weeds, and must be fed regularly with insects. It must be remembered too that many carnivorous aquatic creatures prey on water spiders, and several of the larger insects are among their enemies.

Another family of spiders—*Lycosidæ*—have aquatic, or rather semi-aquatic, representatives. They run on the surface, or live almost exclusively on the banks of ponds and streams, and prey largely on aquatic insects.

The members of this family may be known by the arrangement of the eight eyes, of which four are placed in a row in front, and the remaining four, which are larger, in the form of a square behind them. The abdomen is oval, and the third and fourth pairs of legs are shorter than the others.

One of them, *Dolomedes fimbriatus*, is a very pretty creature, its hairy brown body being marked with yellow. It measures nearly an inch in length. It chases its prey on the surface of the water, but runs on the floating leaves of water lilies and other plants more than on the water itself, and is found principally in the sluggish streams of the fens.

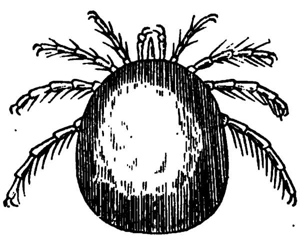


FIG. 182.—A WATER MITE (*Hydrachna*), MAGNIFIED

Other smaller species of this family are similar in habit, and one or two of them even dive below the surface when threatened from above.

Finally, a brief reference must be made to the Water Mites, which belong to the same class as spiders. Of these there are several species, varying much in size; some being almost microscopic, while others are nearly a quarter of an inch in length.

The species figured belongs to the genus *Hydrachna*, some of the members of which are very common in our ponds, where they swim about steadily by the rapid movements of their fringed legs. They undergo metamorphoses when young, and it is a curious fact that the larva has only six legs, while the adult has eight.

Most Water Mites seem to have a remarkable power of resisting the action of certain powerful substances. I once placed a number of them in a small tube of fifty per cent. alcohol, and then hermetically sealed the tube. After this was done I was surprised to see the mites swimming about, apparently with as much comfort as when they were in water ; and nearly two hours had elapsed before they ceased to show signs of life.

CHAPTER X

AQUATIC INSECTS

No part of the pond-hunter's work could possibly be more interesting than the observation and study of aquatic insects; for not only are these creatures generally very active in their movements, and the movements also extremely varied, but most species exhibit marked changes in structure and habits as they develop; and, moreover, the number of species is so large, and their distribution so wide, that insect life is rarely wanting among the takings of the net, but often, if not generally, forms the most prominent feature.

And it is not only in ponds that we find insect life predominating above all other forms. Every stream, even to the impetuous mountain torrent, has its insect population. The air literally swarms with them except in the coldest climes, and there are many species which retain their activity in the season of biting frosts. The soil harbours its thousands; myriads seek their food on all kinds of vegetable life; some bore into the very heart of trees; and others live in the blackest atmosphere of caves. Brackish tidal waters often teem with them, and even the sea has its own particular species from this extensive group.

Insects have been assigned a place at the very head of the invertebrates. They are mostly of small size, the largest of them being much inferior in this respect when compared with many of their crustacean cousins. Like the latter, they exhibit a very complicated external framework, with highly developed appendages, some of which give them a most amazing power of locomotion. The internal anatomy too points to a high position in the scale of life; but it is the superior intelligence displayed by a large number of species that awards them the place of honour at the summit of the scale of the invertebrate sub-kingdoms.

The term 'insect' signifies 'cut into,' and at once points to the most obvious characteristic by which the creatures of this sub-kingdom are to be distinguished from those of all the others, for the body of an insect in its perfect state is usually divided by distinct constrictions into three main parts—the *head*, the *thorax*, and the *abdomen*; and the constrictions are often so deep that the head is joined to the thorax by a very narrow and almost threadlike neck, or the abdomen connected with the thorax by an equally slender waist.

All three of these divisions are further divided into ringlike segments, often very indistinct in the foremost divisions, but usually well marked in the abdomen. Several of the segments bear each a pair of appendages, as we observed was the case with the crayfish and the freshwater shrimp; and where no external line of division is visible between the segments, the pairs of appendages without, and the arrangement of nerve ganglia within, both aid us in mentally separating those which have become so far fused together as to obliterate the external lines of union.

Thus the head of an insect is regarded as being made up of from four to six or more segments. The thorax consists of three segments, each of which bears a pair of legs. The abdomen is of eight segments, none of which have true walking limbs; and to these are often appended two or three others, more or less modified, and forming together what is known as the post-abdomen.

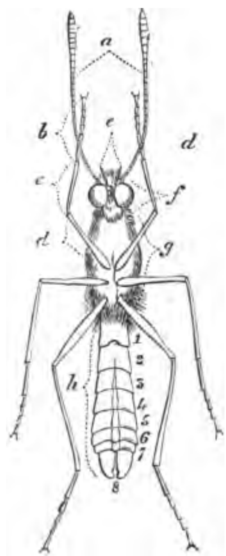


FIG. 183.—BODY OF AN INSECT, UNDER SIDE

a, antennæ; *b*, tarsus; *c*, tibia; *d*, femur; *e*, palpi; *f*, head; *g*, thorax; *h*, abdomen, with segments numbered

As already stated, insects undergo marked changes in form and structure during their growth and development. In most cases the changes are two in number, so that they exist in well-defined forms, known respectively as the *larva* or *grub*, the *pupa* or *chrysalis*, and the *imago* or *perfect insect*. We shall first note the general structure of the perfect form, and then pass on to an observation of the earlier stages, and of the metamorphoses through which the insect passes during its development.

The head of the perfect insect bears a pair of *antennæ*, each of which is made up of a number of joints like the antennæ of crustaceans. These appendages are sometimes simple, and either pointed or thickened at the extremity; sometimes they are pectinated or comblike, or the tip may be furnished with a number of flat leaflike plates. They are the organs of touch and of hearing, and, according to some investigators, are also the seat of the sense of smell. In some insects, too, they are undoubtedly a means of communication.

The eyes are usually large, and compound like those of crustaceans, each filament of the optic nerve having its own

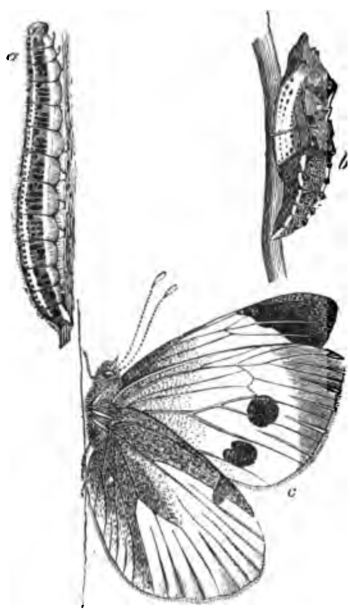


FIG. 184.—THE STAGES OF AN INSECT

a, larva; *b*, pupa; *c*, perfect insect

FIG. 185.—SECTION OF THE EYE OF AN INSECT, MAGNIFIED

crystalline cone, pigment sheath, and facet of the cornea. The number of cones is often very large—over two thousand in the eye of the common house-fly, and from twenty thousand to near thirty thousand in the eyes of dragon flies.

The mouth is situated on the under side of the front of the head, and varies considerably in structure according to the habits of the owners. There are two lips, the upper or *labrum*, and the lower or *labium*; and between them, in many species, lie two pairs of jaws which move horizontally.

The *labia* correspond with the second pair of jaws in the cray-fish, but are usually united in insects. They bear a pair of feelers which are called the *labial palpi*.

In case where the jaws are well developed the upper pair (*mandibles*) is used for biting, and the lower (*maxillæ*) for chewing; and the latter, like the labium, bear another pair of feelers, which are termed the *maxillary palpi.*

These biting and chewing organs, however, undergo strange modifications in the different orders of insects. In butterflies and moths, for example, they are not in the least adapted for the division of solid food, but form a long tube through which these insects suck the sweet juices on which they feed.

In these insects the maxillæ are long and slender, and each one is grooved throughout its length, and shaped in such a manner that when the two are brought into apposition they form a long tube. Each maxilla too contains a second tube, running parallel with and just beneath its groove; and thus a transverse section of the compound structure, which is called the *proboscis*, reveals three distinct tubes, one of which is central, and the other two lateral. This proboscis is retractile, and, when not in use, is neatly coiled into a close spiral which lies partially concealed between the two large labial palps.

In some of the *Hymenoptera* the upper lip and the mandible are both adapted for biting solid substances; while the lower lip and the maxillæ are grooved like the latter organ in butterflies and moths, so that they form a sucking tube when brought into apposition.

In the common house-fly we see another interesting modification of these appendages of the mouth, for here the labium forms a sheath, within which the mandibles and the maxillæ, both reduced to a simple bristle-like form, are encased.

These are only a few of the wonderful modifications of the mouth appendages of insects, and others will be dealt with when we come to examine the structure of the aquatic species which more directly concern us; but we must now pass on to the structure and arrangement of the limbs.

These consist of three pairs of legs, and usually one or two pairs of wings; but it must be remembered that the latter are not limbs in the strict morphological sense of the term, being merely modified extensions of the body wall, supported and strengthened by ribs or rays of a horny substance, about which I shall have some remarks to make presently.

One pair of legs is attached to each of the three segments of the thorax. Each consists of five distinct parts, covered with a hard chitinous exo-skeleton like that which surrounds the body.

The basal joint is the *hip* or *coxa*, beyond which is the short ringlike *trochanter*. The third is the *thigh* or *femur*, the fourth the *shin* or *tibia*, and the last the *foot* or *tarsus*.

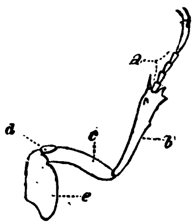


FIG. 186.—LEG OF AN INSECT

a, tarsus; *b*, tibia; *c*, femur; *d*, trochanter; *e*, coxa

The last named is made up of several small joints, varying in number, and usually terminating in a claw or claws, frequently with broad discs which enable the insect to adhere by suction.

The accompanying woodcut gives an idea of the general structure of the leg of an insect, but of course we shall be prepared to meet with many interesting and peculiar modifications in the arrangement, joints, and form of the limb in the various aquatic species which we shall examine.

When the winged insect has just completed its final metamorphosis the wings are soft, and often more or less folded. Soon, however, they will have developed to their full dimensions, and shortly after will be dry and rigid and adapted for flight.

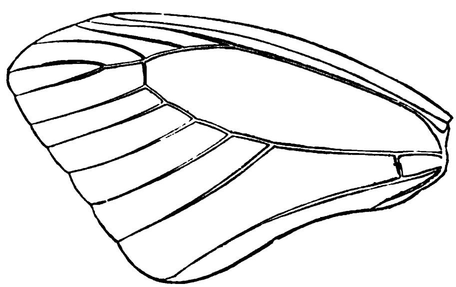


FIG. 187.—WING OF AN INSECT, SHOWING THE RAYS OR NERVURES

Each wing consists of a membrane, usually thin and transparent, sometimes quite naked, but often clothed with minute scales or a soft hair. In some instances, however, the fore pair are wholly or partially composed of a hard horny or chitinous substance, in which case they are not adapted for flying, but merely serve as a protection for the hindermost membranous pair, which are folded up beneath them.

Thin membranous wings are always supported by hollow rays (*ribs* or *costæ*) of a chitinous material, which give the necessary rigidity to the whole structure without materially adding to the weight. These at first—that is, immediately after the emergence from the pupa case—contain fluid; but within the rays are branches of the *tracheæ* or breathing tubes, which contain nothing but air after the wings are dry.

The arrangement of the wing rays of insects is very varied, some wings being supported by only a few, while others have an exceedingly fine and almost invisible network; and the disposition of these rays is a matter of considerable importance to the student of insect life, since it forms an important basis of classification, not only for the main groups, but also for minor subdivisions of these groups.

When examining the external structures of insects we usually observe small openings in the sides of several of the segments. These are called *spiracles* or *stigmata*, and are the openings of the main air tubes (*tracheal trunks*) which branch off into smaller tubes (*tracheæ*) within the body.

The number of stigmata varies greatly in different insects. Frequently there are nine pairs, but in some insects there are only two or three; and in some of the aquatic larvæ the number is reduced to a single pair.

As a rule there are none in the head, one or two pairs in the thorax, and several pairs at the sides of the abdominal segments, either on the segments themselves or between them. But we do not always find the stigmata at the sides of the body. Sometimes they are situated on the dorsal surface, or the extremity of the abdomen, or even on the ventral surface. And as it happens that these interesting modifications occur principally in the aquatic species, we shall have favourable opportunities of dealing with them in the present chapter. Many aquatic larvæ too, though possessed of well-developed tracheæ, have no stigmata, but the branches of the tracheæ ramify into leaflike or fringed appendages, through the very thin walls of which dissolved oxygen is absorbed from water while the animals are submerged, and carbonic acid gas is at the same time given off in exchange. Again, some of these larvæ, particularly those of certain dragon flies, though they are provided with stigmata in the thorax, do not appear to make use of these openings, but receive their oxygen and give off carbonic acid gas from and to water which is periodically drawn into and expelled from the enlarged terminal portion of the digestive tube, on the thin walls of which the finer divisions of the tracheal system are distributed.

The stigmata of insects are not permanently open, but are provided with a valvular lip by which the opening may be more or less perfectly closed at will. The movements of the lip are produced by the contraction of a special muscle, and, on the subsequent relaxation of this muscle, by the elasticity of the chitinous edge which extends round one half of the stigma.

The main tracheal tubes which start from the stigmata soon give off branches, and these further divide and subdivide within the body of the insect, thus forming a complicated system of air tubes by which the blood is aërated, the exchange of gases taking place through the extremely thin membranous walls. As a rule the branches of each tracheal trunk unite with those of the next, so that each segment of the body is almost equally dependent on all the trunks; and frequently we find all the main tubes of each side connected by a wide longitudinal trunk, and, further, the main trunks of one side are often connected with the corresponding ones of the opposite side by means of wide transverse tubes.

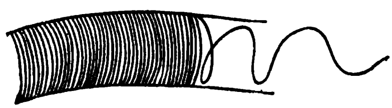


Fig. 188.—Trachea of Insect, showing the Spiral Thread

It is absolutely necessary that the walls of the tracheal tubes should be so thin as to allow the exchange of gases to take place with freedom, and at the same time they should be sufficiently rigid to retain their circular section for the easy passage of air throughout the system. It is further necessary that these walls be sufficiently elastic to regain their normal form after having been altered by the muscular movements of the insect. All these conditions are fulfilled in the structure of the tracheæ, for their thin membranous and easily permeable walls are supported by a coiled elastic chitinous fibre, the arrangement and use of which remind us of the coil of wire that supports an indiarubber gas-tube.

Every muscular movement of the body of an insect probably does more or less to promote air currents in the tracheal system, but insects are capable of special motions by which air may be rhythmically inhaled into and expelled from the air tubes. If you attentively watch a dragon fly—*Platetrum depressum* answers admirably for the purpose—at rest, you will observe that the abdomen is considerably flattened at intervals by the approximation of the dorsal and ventral walls. Such a movement will of course compress the tracheal tubes more or less, and thus cause air to be driven out through the stigmata, providing they are open; while the opposite movement, which immediately follows the compression of the abdomen, allows the tracheæ to recoil by their own elasticity, thus reducing the air pressure within, and causing air to rush in from without.

There is yet another means by which air is set in motion in the tracheæ. The abdominal segments of insects are generally constructed in such a way that each one is capable of sliding more or less with a telescopic movement within the one in front of it, thus considerably shortening the body, which can afterwards be as easily elongated by the action of an antagonistic set of muscles. And these movements, again, by alternately enlarging and reducing the size of the abdomen, cause air to enter and leave the tracheal tubes.

The digestive organs of an insect usually consist of a *mouth*, *œsophagus* or *gullet*, *stomach*, and *intestinal tube*.

In some larvæ which subsist on liquid food derived by suction there is no mouth, but canals or grooves convey the nourishment from the tips of the mandibles direct into the œsophagus. Some perfect insects too, and notably the *Ephemeridæ*, have no mouths. These live for an exceedingly short time in the adult form, sometimes only a few hours, and consequently require no food.

Butterflies, and other insects that subsist entirely on liquid food, while in the perfect form are provided with a special stomach for suction only. This is a thin-walled bag which opens into the œsophagus, in front of the true digestive stomach. In others, which feed on solids, there is a gizzard with a number of horny teeth for mastication.

The glandular or digestive stomach is followed by the intestine, which is usually short in those species which feed on liquids or on solid animal matter, but longer in the case of those which subsist on solid vegetable matter.

The heart is a flattened tube lying along the middle of the back, just beneath the skin, and may be seen pulsating in those insects in which the dorsal skin is transparent. It consists of a chain of chambers, separated by valves, and closed behind. It gives rise to only one vessel, termed the aorta, which proceeds forward from the front extremity; but there are several pairs of openings along the sides. The heart receives the impure blood from the different parts of the body, together with newly formed blood and nutritious matter from the digestive tube. These are then propelled into spaces between the tissues, thus nourishing those tissues, and also in part becoming oxygenated and freed from carbonic acid gas by contact with tracheal tubes. In most insects the blood is colourless, but it is frequently yellow or green, and less commonly of a reddish colour.

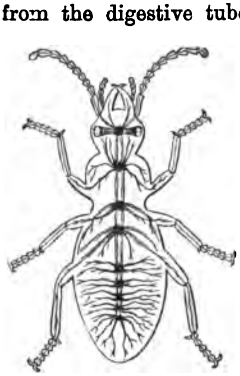


FIG. 189.—NERVOUS SYSTEM OF AN INSECT (BEETLE), SHOWING THE CHAIN OF GANGLIA AND THE DOUBLE CENTRAL NERVE CORD

The nervous system is very similar to that of the crayfish. There is a large ganglion in the head, supplying nerves to the antennæ and the eyes. Three double ganglia in the three segments of the thorax supply the limbs; and behind these lies a chain of ganglia in the abdomen, one ganglion in each segment.

The sounds produced by insects are sometimes brought about by the vibration of little projections of a horny material within an enlarged tracheal trunk. This seems to be the case with the buzzing of flies. But they are apparently more generally produced by the friction of two hard parts of the skin which are provided with minute ridges or tooth-like projections. Thus in the grasshopper the femur of the third leg rubs against a ridge on the front wing; in crickets the two outer horny wings are rubbed together; and in certain beetles the hind leg is rubbed against the side of the abdomen.

Those insects which produce sounds are usually provided with a special auditory apparatus in addition to that in the antennæ, and this is situated on the tibiæ of the forelegs.

Another interesting feature in the structure of some insects is the presence of an organ that is capable of emitting rays of light. This, in the case of the glow-worm, the only British luminous insect, is a whitish organ, situated under the last three segments of the abdomen, and very plentifully supplied with nerves and tracheæ.

We must now pass on to the consideration of the changes which insects undergo during their growth and development, confining our attention at present to those whose metamorphoses are complete.

The eggs are laid by the female on or near the food required by her offspring. They are often arranged in some definite order, and the shells are frequently beautifully sculptured. The female is often provided with an apparatus by which the eggs can be deposited in crevices, or by means of which they may be thrust into animal or vegetable substances. This apparatus may consist merely of bristle-like appendages, or it may take the form of a pair of forceps or little saws; and it appertains to the eighth segment of the abdomen, or is a modification of the post-abdomen.

The young or larvæ are usually of a cylindrical form, and distinctly segmented. The head bears a pair of antennæ, and one or more pairs of ocelli or simple eyes. They are in most cases provided with a pair of jaws that move horizontally.

They are sometimes quite limbless, but usually there are three pairs of walking legs, one pair attached to each of the three segments that immediately follow the head, and which represent the three thoracic segments of the perfect insect. Some of the hindmost segments are often provided with other appendages called prolegs, which not only assist the larvæ in their progression, but also enable them to fix themselves firmly when at rest.

Larvæ are as a rule voracious feeders, and usually grow very rapidly. The skin does not keep pace with the body in its growth, and consequently soon becomes stretched. The larva then ceases to eat for a time, and remains at rest, awaiting the moult or casting of the skin. The skin soon splits behind the top of the head, and after a series of contortions the larva relieves itself of its rent garment. The new skin thus exposed is at first very soft and affords a very imperfect protection to its owner; but it soon hardens, and the creature returns to its food as vigorously as before.

Several such moultings take place before the larva is fully grown, and then it prepares for its change to the pupa, and in some cases for a longer or shorter period of quiescence.

Some burrow into the ground, or seek out a sheltered crevice in which to spend this stage. Many are provided with a spinning apparatus, and either construct a silken cocoon, or, by means of silk threads, bind together pieces of earth, wood, leaves, or other substances to form a home, or tie themselves up in leaves which they have folded, or suspend themselves by means of bands or threads of silk.

The spinning apparatus consists of two tubular glands in the abdominal segments, which secrete a tenacious fluid. These glands open by a small aperture in the lip; and the fluid dries immediately on exposure to air, thus forming an exceedingly thin fibre of silk.

After the larva has completed the preparations for its quiescent period, it undergoes its last moult; and the insect then generally presents quite a different appearance. The limbs of the perfect insect are now distinctly outlined in the new skin, or even plainly visible where the new covering is transparent, as is often the case; and the same is true of the antennæ, proboscis, and other appendages.

The skin now hardens, and the insect is a pupa, often with no means of obtaining food, and usually no power of motion beyond that of wriggling its hindmost segments.

The time spent in the pupal condition varies much in different species. Sometimes it is only a few hours; but often the whole winter, and in some cases even more than a year, is spent in this inactive form. As a rule, however, aquatic insects spend the winter as larvæ, and the pupal condition lasts for only a short time.

When the time arrives for the final metamorphosis, the pupal skin bursts, and the perfect insect creeps out of its case, and suspends itself by its legs till its wings are capable of supporting its body in the air.

At first these appendages are moist and soft, and frequently much below their normal size. They soon attain their full dimensions, however, and shortly after become dry and rigid; and the winged insect then takes to flight, seeks its mate, and engages itself in the propagation of its species.

Such is a brief life-history of those insects whose metamorphoses are complete; but it must be remembered that many exhibit scarcely any change in form during their whole career. Some there are that never develop wings at all, and others in the perfect state differ from their larvæ or their pupæ but little except in the possession of wings.

We have hinted at two features in which larvæ differ materially from the perfect insects into which they develop—namely, that the former are voracious feeders that grow with rapidity, while the latter do not grow, but are to be regarded as the adults, gifted with prodigious powers of reproducing their species. In accordance with these facts we should naturally expect to find corresponding differences in structure. And such is really the case; for while in larvæ we find the organs of digestion developed to an astonishing degree, these organs are generally suppressed in the perfect insects, and the organs of reproduction take a prominent place in the structure.

We have also referred to an extreme case in regard to certain insects (*Ephemeridæ*) which require absolutely no food during the short term of their adult existence; and also to others (such as the *Lepidoptera*) which devour enormous quantities of solid food in the larval form, but partake only of an inconsiderable amount of *liquid* food in the adult stage.

There are, however, remarkable exceptions to this rule as far as the food and the digestive organs are concerned; for many insects, among which a number of aquatic species take a prominent place, are equally voracious in all their stages; and these often exist for a long period in the adult form, in some instances even for a longer period than the larva. As an example we may mention the great carnivorous water beetle (*Dyticus marginalis*), which often sees a second summer after arriving at maturity.

As we proceed in the examination of aquatic species, we shall observe many points in which these differ in structure from the terrestrial and aërial forms. Thus we shall note that their build is especially adapted to their aquatic habits, that their breathing apparatus is modified in accordance with their mode of obtaining air, and that the specific gravity of their bodies is also suited to their requirements as floaters or bottom feeders, as the case may be.

In the first chapter were enumerated the different orders of insects, and the chief characteristics by which they are distinguished briefly stated. We shall now examine the commonest species to be met with in our ponds and streams, the list being far too long to allow of even a bare mention of all of them; and we shall deal with the groups in the order in which they have been previously named.

The Rhynchota or Hemiptera

In this order either the metamorphoses are incomplete or there are none at all, and wings may be present or absent in the mature insect. The larvæ are as a rule much like the imagines, but of course always without wings, and the insects do not pass through any quiescent stage corresponding with the pupæ of the higher orders.

All of them partake of liquid food only, and this is obtained by suction from plants and animals; hence we find the mandibles and maxillæ are not adapted for chewing, but modified so as to form part of a suctorial beak. The labium is produced into a long and sharply pointed tube, and within this work bristle-like processes of the mandibles and maxillæ, the whole forming a very effective organ for piercing and sucking. It is also interesting to observe that neither the maxillæ nor the labium is provided with palpi.

FIG. 190.—MOUTH OF A BUG
a, antennæ; *l*, labium; *m*, bristles of the mandibles and maxillæ; *e*, eye

The *Rhynchota* are divided into two sections—the *Heteroptera* and the *Homoptera*.

The *Heteroptera* include the bugs, some of which inhabit water, while others derive their food from plants or are parasitic on terrestrial animals.

The word *Heteroptera* signifies 'varied-winged' (Gr. *heteros*, another or different), and the section is so named because the basal portion of the forewing is usually composed of a firm horny material, while the other portion is thin and membranous. In some species the wings are never fully developed, and in others only a portion of the adult individuals have their wings perfected, the remainder being entirely deprived of the means of aërial locomotion. The pointed beak is not only an organ of suction, but is used by several species as a means of defence. The bodies of most of the *Heteroptera* are very flat, so that they can readily conceal themselves in narrow crevices.

The *Homoptera*, or 'same-winged' insects (Gr. *homos*, same), are so called because both pairs, at least of those that *have* wings, are membranous. The section includes plant lice, cuckoo spits, and frog hoppers. They differ from most of the *Heteroptera* in that their bodies are not flat, but very convex.

The *Heteroptera*, which we have more particularly to consider here, are divided into two main sections—the *Aurocorisa* or Air Bugs, also commonly known as Land Bugs; and the *Hydrocorisa*, or Water Bugs. The former are mostly quite outside our province, but they happen to include some insects which, although they spend much of their time *on* the water, do not obtain air for respiration *from* this element, but inhale it direct from the atmosphere. The latter section contains some well-known aquatic species.

We will first examine some of the aquatic *Aurocorisa*, popularly known as Water Gnats and Pond Skaters; but, before commencing our descriptions of aquatic insects, it will be well to mention the fact that the number of species which may from time to time become entrapped within the net of an enthusiastic pond-hunter is so great that we shall have to be content with accounts of representatives only.

Water Gnats (*Hydrodromica*)

On the surface of almost every pond and sluggish stream during the summer months, and even during the milder days of the winter, we may see numbers of brownish insects, with very slender bodies and long and exceedingly thin legs, walking on the surface of the water; and others, of a somewhat similar build, darting about on the surface with a series of leaps or jerks.

The former belong principally to the genus *Hydrometra*, or Water Measurers, and are commonly known as Water Gnats, their slender forms being very suggestive of wingless gnats.

As a rule we find them in little sheltered nooks at the margins of ponds and streams, and also frequently making their way among the herbage of the banks; and their movements are so sluggish that they are easily taken in the net or captured with the hand.

If we examine one of these creatures we are at first inclined to compare it with a spider, for it appears to have eight legs. A closer examination, however, shows that it has *six* legs only, and these almost as fine as a hair; while the two foremost appendages are the antennæ, so disposed that they somewhat resemble a pair of limbs.

The slender body is only as thick as an ordinary pin. It is distinctly segmented, and covered with a hard chitinous substance, but has only the rudiments of wings.

The thorax is elongated, and the three pairs of legs are attached at the sides, and not beneath, as is usually the case with aquatic insects.

The head is most peculiar. It is elongated to such an extent that it is usually longer than the thorax, and nearly as long as the abdomen. It is thickened behind, where it articulates with the thorax, very thin throughout the greater part of its length, and enlarged again at the front extremity, where it gives rise to the antennæ and the beak. The eyes are small but prominent, and are situated at the sides of the middle and thinnest part of the head.

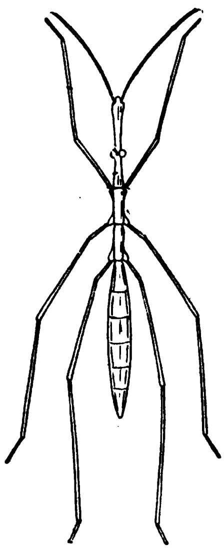


FIG. 191.—*Hydrometra stagnorum*

The beak is long, but not so long as the head, and is directed backward beneath the latter.

Locomotion is effected principally by the middle pair of legs when the creature is progressing on the surface of water, the foremost pair being kept in readiness for the seizure of its prey, while the hind legs are usually directed well backward, so that they serve the purpose of a rudder as well as assist in the onward movement.

Any one engaged in observing the movements of *Hydrometra* for the first time may well be astonished at the manner in which the insect keeps itself entirely above the surface. The extreme lightness of the creature may be in itself regarded as sufficient explanation to those who are not acquainted with the physical properties of the surface on which it treads.

It is a well-known law that a floating body rests on water in such a position that it displaces its own weight of water. Thus a piece of wood weighing one ounce will if thrown into a pond be submerged to such an extent that it has pushed from beneath it exactly one ounce of the liquid.

But if we closely watch *Hydrometra* as it rests on the water, we find that no part of its body is beneath the surface—that even its feet are dry. And yet we have some evidence to show that the weight of the insect does tell a little, for under each foot is a slight concavity; and the surface, thus bent, has the effect of refracting rays of light, and so producing small illuminated spots on the bottom when the creature stands on shallow water.

How is it, then, that the legs of Hydrometra, and, of course, of other insects that walk or run on water, are capable of pressing down the surface, and yet do not penetrate it ?

In order to answer this question we cannot do better than resort to one or two very simple experiments.

Cover a piece of glass with a very light layer of oil or beeswax, apply so little indeed that it is not even visible on the surface. Now lay the glass on a table, and let a few drops of water fall on it. On striking the glass the drops break up into little globes of water, which run along like little balls for a short distance, and then remain in the form of little spheroids, slightly flattened beneath by their own weight.

Again, arrange a fine jet of water so that it may fall perpendicularly into a pond or large aquarium, and you will see numerous little globules of water, formed by the falling drops, rolling on the surface just as a toy ball runs on a solid ground.

Now, why should the water remain in the form of globules on the glass; and why should the rolling drops on a pond refuse, at least for a time, to unite with the water beneath it ?

The reason is this: the free surface of water is always covered by a kind of invisible film, formed by the external molecules; and this film cannot be broken without a certain amount of mechanical force, but when once broken, the intruding substance passes through the liquid easily.

Where is the schoolboy who has not demonstrated the presence of this 'surface film' by gently lowering a needle on to the surface of water, and thus causing it to float ?

The needle is made of a substance about eight times the weight of its own volume of water, and yet it cannot break through the film. But apply just sufficient pressure to push one end of the needle through the film, and it sinks so rapidly that we can hardly trace its path.

As a striking instance of the supporting power of the surface film, make a small sieve with rather fine wire gauze, say about three inches in diameter, and about one inch deep. Water thrown into such a sieve will of course run out quite readily; and if an attempt be made to float the sieve as a boat, water will as readily run in and fill it, and in a moment the sieve is at the bottom.

But now dry the sieve, and then dip it into melted paraffin. It comes out covered with a very thin and almost invisible layer of this substance. Part of it, too, stretches across the meshes of the gauze, thus closing the holes; but this may be removed at once by tapping the sieve on the table or blowing one or two sharp puffs of air at it while the paraffin is still hot.

Now pour water into the sieve, and you find that you can fill it almost or quite to the top. Also put the empty sieve on water, and the water below it refuses to enter, even though pressed by the weight of the metal. So much resistance indeed does the surface of the water now offer to the passage of the metal wire, that a weight of two or three ounces may be placed in the sieve without breaking the film.

This experiment proves beyond all doubt the presence of a kind of invisible skin on the surface of water, and also shows that some substances have less power of breaking through it than others. The substances that most easily break through the film are those which are most easily wetted by water, while those which are most effectually resisted by it are those which come out dry after immersion.

Let the reader, when an opportunity occurs, catch a *Hydrometra*, or any other insect that runs or jumps on water, and immerse it, and he will notice that it emerges in a perfectly dry state. Nay more, he may even find that the creature has considerable difficulty in breaking the surface film on its upward journey, notwithstanding its remarkably low specific gravity, and consequent great tendency to rise when under water.

This latter feature of the surface insects may also be demonstrated by means of the little paraffined sieve. Thus, invert the sieve and push it under water. Then put beneath it a cork sufficiently large to make it rise. On reaching the surface, the film may be seen to be heaved up above the normal level, but yet it refuses to break and give passage to the metal, even though the upward force is considerable.

I cannot refrain from mentioning one other property of the surface film, again introducing it by means of a simple experiment. Blow a soap bubble on the end of a piece of glass tubing, and then leave the tube open. The bubble then gradually collapses, driving the air back again. Or, as an alternative, bend up a piece of wire into the form shown in fig. 192, and fix a piece of cotton loosely across the circle. Now immerse the whole of the circle into soap solution, and on withdrawing it a film of the solution will fill the circle, and the thread will be found to move easily in the film without breaking it. Next touch the film on *one* side of the thread with a hot wire. It immediately breaks on this side, but the film on the other side of the thread pulls the latter sufficiently to form a strong curve.

These two simple experiments show that the film is decidedly elastic—that it always exerts a considerable pull, which is spoken

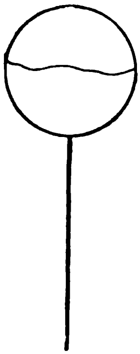


Fig. 192.—Wire Ring and Cotton Thread to demonstrate the Elasticity of the Water Film

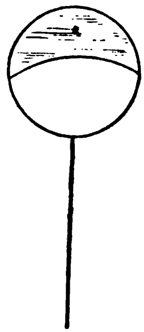


Fig. 193.—The Thread pulled by the Elasticity of the Film

of as the *tension* of the film. It must be remembered, however, that the film in these cases really consists of two films, with an extremely thin layer of the solution between them.

An apology may seem necessary for digressing thus far on a subject that may seem foreign to the purpose of this work; but I have thought fit to do so because it is impossible to understand the movements of many aquatic creatures, and these include others than insects, without a knowledge of the properties of the surface film.

Now to return to the *Hydrometra.* In these creatures the metamorphoses are incomplete. The larvæ and pupæ are both very much like the perfect insects, but the former never have wings, and the latter only possess these organs in a very rudimentary state. The perfect insects, too, often have wings in an undeveloped form. Still there is no difficulty in distinguishing between the perfect and the earlier stages; for in the latter the larvæ, as is generally the case, are covered with a soft and yielding skin, while the perfect insects are always protected by a hardened horny integument. I have already hinted at the necessity for this difference in the chapter giving a general outline of insect life, where, it will be remembered, I spoke of the larva as a growing grub, undergoing several moultings while the loose covering expands as the creature increases in size in the intervals between. The perfect insects, on the other hand, do not grow, and therefore admit of the protection that can be afforded by a chitinous coat of armour.

But, it may be asked, how is it that insects such as the *Hydrometra*, and many others, which eat raveuously in *all* their stages, cease to grow as soon as the mature form has been attained? The reason is, and it applies to animal life generally, that the food taken over and above that required to repair the waste to the system, and which in the earlier stages adds to the size, is utilised in the mature animals for the function of reproduction.

It may be mentioned that *Hydrometra stagnorum* is the only British species of its genus; but there are a few other insects of similar structure and habit.

Pond Skaters (*Gerridæ*)

Allied to the *Hydrometra* are the Pond Skaters (genus *Gerris*), which may be distinguished from the former, even at a considerable distance, by their habit of sliding on the surface film of the water in

Fig. 194.—*Gerris gibbifera*, ENLARGED

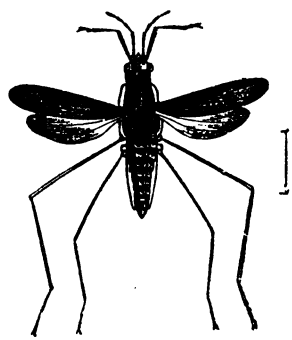


Fig. 195.—*Gerris argentata*, ENLARGED

a series of long jerks, and even sometimes of leaping from one point to another. They are much more active than the *Hydrometra*, and instead of confining themselves to the sheltered nooks close to the banks of ponds and streams, venture well out into the open, and often allow themselves to be drifted along by the wind, at which time their progress is naturally smooth and steady.

When alarmed, they sometimes dive below; and it seems probable that this is also done at times in search of food, for I have seen one feeding on a larva that was probably brought from the bottom, for the larva was one of the bottom feeders that never come to the surface.

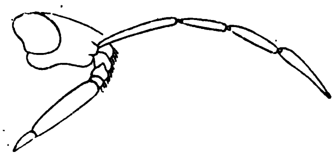


FIG. 196.—THE HEAD OF *Gerris argentata*, SHOWING THE BEAK AND ANTENNA, ENLARGED

Like the *Hydrometra*, the insects of this genus somewhat resemble spiders, the antennæ looking something like a fourth pair of legs except at a close view. In fact they are even more like spiders than their allies, for their bodies are not so slender. And this is even more true of the larvæ, for at this stage the abdomen is only slightly developed, and therefore the body is still wider in proportion to its length.

The head is not long and slender as in *Hydrometra*, but the eyes are prominent, and the antennæ are composed of four joints, the first of which is much longer than the others.

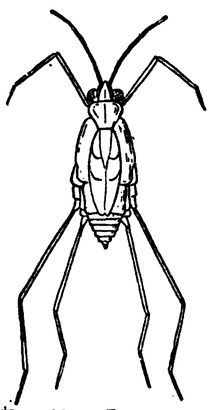


FIG. 197.—LARVA OF A POND SKATER, ENLARGED

The beak also is composed of four joints, and contains four bristles by which the insect pierces its prey. It is long, and is always curved under the head; and the creature is consequently compelled to hold its prey beneath its thorax while it sucks out the juices. It will be seen from fig. 196 that the third joint of the beak is much longer than the others.

The structure of the thorax is peculiar. The first pair of legs, which are used as prehensile organs only, are placed at the front of the first segment, and this segment is usually so long that the second pair of limbs, which of course are attached to the second segment, are widely separated from the first. So long indeed is the segment in question, that the second and third pairs of limbs are often nearer to the tip of the abdomen than the head.

The result of this peculiarity of the thorax is even more marked in the larva, for at this stage the abdomen is so short that the second and third pairs of legs appear to arise from the hindmost portion of the body.

Nearly the whole surface of the body is clothed with a short velvety hair which stands out at right angles to the integument; and this hair so effectually resists the water that the insect never becomes wetted when immersed; and consequently, when it is below the surface, the body is covered with a film of air, and looks as if it were bright metallic silver.

When forcibly pushed below the surface of the water, the *Gerris* is often unable to break through the film as it ascends; and, in its struggles to find an exit, it will sometimes turn over on its back, and walk in an inverted position on the film, being kept in close contact with the surface by its low specific gravity. At such times an observation with the aid of a hand lens will show that the water is pushed up into a minute heap at the extremity of each of the limbs employed in this mode of progression.

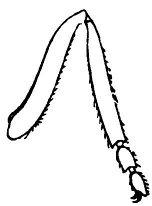


FIG. 198. — FORELEG OF *Gerris argentata*, ENLARGED

The two front legs are normally bent under the thorax, but these limbs are extended when the *Gerris* is in the act of seizing its prey.

The middle legs are thrown well out at the sides. These are used for propulsion; and being very long, they give the insect a good leverage, enabling it to take strides of considerable length.

The hind legs project backwards. They are not used much for propulsion, but serve the purpose of a steering apparatus.

Some only of the adults have their wings fully developed; in others they are short, so much so that they have no power of flight.

The outer wings are strong, of a horny nature, and of a very dark colour. The others are thin and membranous, and are folded.

The larvæ of Gerris may be found on ponds throughout the summer months. They skate on the surface of the water, much like the adults, but, unlike the latter, are often to be seen on submerged weeds.

The insects hibernate in the adult stage, but they do not seem to be heavy sleepers, for they may be seen at large on mild days in

PLATE III.

3c

1 2a

1a 3b

2 3a

3

4

West, Newman imp.

... are not so active at this time as they ... and may sometimes be seen at rest, with all ... under their bodies, so that they look just ... floating stick.

... on pondweeds, to which they are attached by ...

... contains ten British species, all of which are ... general structure and habits.

Water Bugs

... the *Hydrocorisa* or Water Bugs, which ... from the Water Gnats both by their ... bodies are usually of a stouter build, ... many plant bugs. The antennæ ... of Water Gnats, but are always ... in cavities ... eyes.

... also use the ... limbs as organs of prehension ... locomotion, but, ... those previously described, ... power of walking, skating ... jumping on the surface ... are bottom feeders, ... spend their time almost ... on the ... or on the water weeds ... coming to the surface ... for the purpose of obtaining air, or when about to migrate, or ... a hiding place in which to hibernate.

... section of the *Heteroptera* contains some well-known and ... ing insects, a few typical examples of which we will ...

Water Boatmen (*Notonectidæ*)

(Plate III, figs. 1 and 1A)

... aquatic insects to fall into the net of the ... the common Water Boatman (*Notonecta* ... abundant is this creature that it is often a very ... find a pond, large or small, that does not ...

... matter to learn the life history and habits ... natural haunts; but fortunately it is easily ... and rea... ... ately large aquarium, and its interesting ... ments ... it a most desirable aquarium pet.

... have in ... a splendid example of adaptation to ... The form of the body forcibly reminds one of that of ... boat, for the back of the insect is bluntly keeled, and the

PLATE [illegible]

the middle of winter. They are not so active at this time as they are in the summer, and may sometimes be seen at rest, with all three pairs of legs folded under their bodies, so that they look just like a little piece of floating stick.

The eggs are laid on pondweeds, to which they are attached by a glutinous substance.

The genus *Gerris* contains ten British species, all of which are very similar in their general structure and habits.

Water Bugs

We have now to deal with the *Hydrocorisa* or Water Bugs, which may be readily distinguished from the Water Gnats both by their form and their habits. Their bodies are usually of a stouter build, or they are flattened like those of many plant bugs. The antennæ are not conspicuous, as in the case of Water Gnats, but are always closely concealed in cavities below the eyes.

These insects also use their fore limbs as organs of prehension rather than of locomotion, but, unlike those previously described, have not the power of walking, skating, or jumping on the surface of the water. They are bottom feeders, and spend their time almost entirely in the mud or on the water weeds, coming to the surface only for the purpose of obtaining air, or when about to migrate, or to seek a hiding place in which to hibernate.

This section of the *Heteroptera* contains some well-known and very interesting insects, a few typical examples of which we will now examine.

Water Boatmen (*Notonectidæ*)
(Plate III, figs. 1 and 1a)

One of the first of aquatic insects to fall into the net of the young pond-hunter is the common Water Boatman (*Notonecta glauca*). In fact, so abundant is this creature that it is often a very difficult matter indeed to find a pond, large or small, that does not harbour it.

It is not a very easy matter to learn the life history and habits of this insect while in its natural haunts; but fortunately it is easily kept and reared in a moderately large aquarium, and its interesting movements certainly make it a most desirable aquarium pet.

We have in this species a splendid example of adaptation to aquatic life. The form of the body forcibly reminds one of that of an inverted boat, for the back of the insect is bluntly keeled, and the ventral surface flat; and when we observe that the creature swims in an inverted position (hence the term *notonecta*, which means 'back-swimmer'), the likeness is seen to be still more perfect. There is this difference, however, between the shape of an ordinary boat and that of the body of *Notonecta*—the former is pointed in front, but not behind; while the latter is blunt in front, and tapering behind.

FIG. 199. — THE WATER BOATMAN (*Notonecta glauca*)

The head is moderately large and protected by a very hard and smooth integument; and the large eyes are rendered very conspicuous by their dark brown colour and brightly burnished surface.

The front segment of the thorax also is covered with a hard and burnished integument; and there is no doubt that this feature must materially compensate for the general bluntness of the fore part of the body, by reducing the friction as the creature darts through the water.

Behind this polished covering is a large black triangular plate, with its apex directed backward. This is also a portion of the covering of the thorax, and is named the *scutellum*. The presence of this plate is very characteristic of bugs generally, and it often attains a very great size. In the present species it may be easily mistaken for a portion of the elytra or outer horny wings, of which we shall speak presently; but there is no risk of this confusion when the wings are extended (fig. 200).

FIG. 200. — *Notonecta glauca*, WITH WINGS EXTENDED

The wings of *Notonecta* are powerful, and its flight rapid. The outer pair are partly horny and partly membranous—a feature which has already been mentioned as characteristic of the *Heteroptera*.

A close examination will show that each of these wings consists of three distinct parts. The largest of these is an isosceles triangle, the base of which forms the front margin when the wing is extended. The usual colour of this triangle is a dark brown, with a long triangular yellow patch near the body, and another light but less defined patch at the other extremity. The inner side of this triangle forms the base for a second of similar shape but much smaller, which is almost covered by a yellowish patch much like that on the first. It must be remembered, however, that the colour of this insect is very variable, the dark tints of the outer wings being often almost entirely wanting.

These two parts together form the horny portion of the wing; and the third, which is attached to the other side of the largest triangle, and forms the hindmost part of the tip of the wing, is the membranous portion.

The outer wings somewhat resemble those of beetles, being organs of protection rather than of flight; and, like these, they are commonly spoken of as the *elytra*.

The inner wings are beautiful objects, not at all like what we should expect to see in the case of a creature known by the detestable name of 'bug.' They are extremely delicate, and would be almost invisible were it not for the dark but exceedingly fine nervures which support the fragile membrane and the beautiful iridescence exhibited by them when they reflect light at certain angles.

As regards the legs, it will be seen that the first pair are short, and usually kept folded beneath the thorax. They are not used as organs of locomotion at all, but serve to hold the creature's prey, and to anchor its body to weeds and to objects which lie on the bed of the pond. This latter use is a highly important one, for the specific gravity of *Notonecta* is very low, and it therefore requires a strong limb to keep it below the surface for a great length of time.

The second pair of legs are much longer, and are employed both when the insect is pushing its way among the foliage and stems of aquatic plants, and when it wishes to anchor itself to submerged objects to rest.

The hindmost limbs are the longest of all, and are unmistakably *the* organs of locomotion. They are long and strong, and moved by powerful muscles. The last segment is fringed with a row of stiff bristles, and thus the limb forms an admirable swimming organ. In fact, we have here the one feature above all others which justifies the popular name of 'boatman' as applied to this insect.

No one who has ever seen *Notonecta* in motion in its native element could fail to see its resemblance to a boat. The long hind legs are stretched out at right angles to the body, and the latter is urged forward with considerable speed by their oarlike motion. There are these differences, however, between the motion of the oar and that of *Notonecta's* third leg: The oar is rigid, and is lifted out of the water during each back stroke; but the leg of the insect is gracefully bent while performing the back stroke, so that it offers less resistance to the progress of the owner; and it always remains submerged while the animal swims. Then, again, the experienced oarsman reduces the resistance by turning the edge of the blade of the oar to the water at the end of each stroke, just while it is being raised out of the water; but the same end is gained in the case of our Water Boatman, not only by the bending of the limb already referred to, but also by the depression of the bristles which form the blade, for these bristles can be made to stand out or lie close, at the will of the insect.

The limbs of *Notonecta*, at least the front and hind pairs, serve other purposes than those already mentioned. Take the creature out of the water, and lift up its elytra by means of a blunt pin. It will resent this liberty of yours by endeavouring to keep the wings tightly closed; and, as soon as you have ceased your endeavours, both the hind legs will be used in vigorously replacing the wings, as well as in a final brushing after they are set in their proper position. The forelegs, too, are often employed in brushing over the hard and polished integument of the front parts of the body.

The positions taken up by *Notonecta* when at rest are highly characteristic. If anchored to a submerged object by means of its forelegs, the hind legs are fully extended in such a manner as to suggest a boatman resting on his oars; but sometimes a paddling movement is maintained the whole time, as if the creature were keeping itself in practice for a sudden dart in the event of the approach of a suitable victim to satisfy its hunger.

As soon as it releases its hold we observe its tendency to rise, owing to the low specific gravity of its body. So light indeed is the insect that vigorous efforts are necessary in order to keep itself near the bottom when not anchored.

We observe, further, that during a cessation of these efforts the insect naturally turns over on its back. This of course is due to the fact that the ventral portion of the body is the lightest. Hence, if the creature allows itself to rise in the water without effort, the ventral surface is the first to touch the surface film of the water. As a matter of fact, however, the oars are always held in such a position when the insect rises that they strike the surface film before the body. Then, since these limbs are not able to penetrate the film, they tend to keep the body entirely below it. But, the abdomen being lighter than the head and thorax, the body swings into an oblique position, so that it rests in equilibrium on three points, all of which are being pressed against the surface film by the buoyancy of the insect.

While the insect is in this position we have an opportunity of examining its under surface, and of learning something of its breathing apparatus; but we must not approach too suddenly, or the creature, ever on the alert, will at once dart to the bottom. The under side of the abdomen is now seen to be completely covered with a film of air, which gives an appearance resembling that of polished silver, and is particularly striking when the insect is swimming in bright sunshine. We shall see too that the hairs at the tip of the abdomen project a little above the surface of the water, and that the air entangled between them forms a means of communication between the atmosphere and the layer of air that covers the ventral surface of the body.

Now let us take our *Notonecta* out of the water by making a sudden sweep at it with a small net. Its body is perfectly dry. Indeed the water never touches the lower surface, being kept off by the film of air that remains in contact with it. If we examine the creature we find that this surface is covered with short hairs, the chief of which are arranged in rows on either side; and it is these which entangle the film of air that prevents contact with the water. Further, a lens will reveal the abdominal stigmata in the depressions between these rows of hairs, and if we return the insect to its native element we may even watch the manner in which the air is made to pass over the breathing holes.

It will be seen that the rows of hairs on each side of the stigmata not only serve to entangle air, and thus form a film that communicates freely with the atmosphere above, but they also form clear passages, along which air can pass freely over the openings of the tracheæ. The movements of the air may also be observed under the edges of the elytra, which are sufficiently transparent to allow them to be seen.

The air passes from the tip of the abdomen, along the channels at the sides where the stigmata are situated beneath the edges of the elytra, till it reaches the thorax, also provided with stigmata. Then, having given up some of its oxygen to the tracheal system, and become more or less charged with carbonic acid gas from that system, it escapes in the form of occasional bubbles from beneath the bases of the wings.

If we disturb *Notonecta* while enjoying the benefits of this free communication with the atmosphere, we find that it is unusually buoyant, and consequently has to struggle hard to reach the bottom. This is due to the large amount of air stored beneath the elytra. During its struggles, however, we often observe that a very large bubble becomes disengaged from beneath the shoulders. Also, when the insect has anchored itself, a bubble may still be seen to form at this part, and to grow gradually larger, till at last it breaks free.

Notonecta is entirely dependent on air obtained at the surface of the water, not having any means of absorbing dissolved oxygen. Hence the creature is obliged to make frequent visits to the surface for the purpose of renewing its supplies. In the summer, however, it will often remain at the surface for a long time together, thus apparently enjoying the sun's rays as well as the uninterrupted communication with the pure air.

At times, too, it will turn with its back uppermost, and support itself on weeds in such a manner that it is half out of the water. It may often be found in such a position when the sun is high and bright, thus showing its undoubted appreciation of the light and warmth of summer. At such times the elytra are often raised a little, as if the insect were about to fly; but this is probably only a means of putting the stigmata in direct communication with the free air.

I have spoken of the movements of *Notonecta* in the water, but how does it behave when out of its natural home? Put the creature on the ground, and how awkward is its motion! Its front and middle legs are practically useless. True it can help to drag its body along by means of the latter, but walking is out of the question. The oars are no longer gracefully wielded and feathered, but are jerked so violently that the body is thrown about in a most irregular manner.

But the creature is not always so awkward when out of the water, as every one will admit who has seen it fly. Its flight is rapid and steady, and accompanied by a humming sound; and is usually taken in the evening, though at times it flies in very bright sunshine.

It sometimes takes its flight direct from the water, for, unlike many of the aquatic beetles, it does not necessarily require a foothold while expanding its wings. It will leap out of the water by a strong stroke of its oars, and then suddenly expand its wings before it has had time to fall back. I find, however, that this is not the usual mode of procedure in captivity.

Put a number of the insects into a pan or tub of water. Leave them undisturbed after sunset, but have sufficient artificial light to enable you to watch their movements. You will soon see them climbing up the sides of the vessel which holds them, even if the sides are perpendicular and as smooth as glass. But how can they climb on such surfaces as these, seeing that the legs are not supplied with suckers? Here again the creature makes use of the properties of the surface film of water. In its struggles to leave the water it wets the side of the vessel. The little drops of water then cause its body to adhere, and with its oars pushing against the wet glass, and aided by the tenacity of the films, gradually, and often somewhat laboriously, it finds its way to the edge. Here it obtains a steady foothold, expands its wings, and starts on its flight.

Notonecta is entirely predaceous. It will fearlessly attack an animal larger than itself, hold it firmly under its thorax by means of the forelegs, and then suck its juices till there is little or nothing left but a mere skeleton. If disturbed while feeding, it will swim about with its prey as though its food were dearer than life itself.

Those who have handled Water Boatmen freely probably know something of the power of the beak, for the insect does not hesitate to use this organ either as a weapon of offence or defence. The pain produced by the intrusion of the bristles is so sharp that it is difficult to believe that it is caused solely by mechanical irritation—that no irritant poison has been injected into the wound. But the sensation is of very short duration, and there are no signs remaining which would suggest the presence of any poisonous substance.

From what has just been said it will be seen that the 'bite' of *Notonecta* is not really a bite, not being produced by the approach of two opposing jaws; nor does it resemble the stinging of hymenopterous insects, for in this case a powerful poison is injected into the wound.

The eggs of *Notonecta* are laid singly on the stems of pondweeds or on decaying fragments of aquatic vegetation, each egg being deposited in an incision made by means of a protrusile ovipositor.

The larvæ are much like the perfect insects, but of course have no wings. In the pupæ the wings are rudimentary.

In all three stages the creatures are equally predaceous, and the perfect insect, like many rapacious species, enjoys a rather long existence. In the indoor aquarium it may be kept alive throughout the winter, and, unless the apartment in which it is situated is a very cold one, it remains active the whole time.

Several other insects are often included under the popular title of 'Boatmen,' but they differ from *Notonecta*, which is the only member of its genus, in not having their backs distinctly keeled. In fact they are mostly very flat on the upper side, and their chief right to the title lies in the mode of using their oarlike legs; and even here the resemblance to the true 'boatman' is not nearly so marked as in the case of the species just described.

The Corixidæ

If we take up a position close beside a pond and watch the water intently we are almost sure to see a number of little insects of a dark colour, making a very sudden appearance at the surface from below, and, after a momentary pause, darting away again with great speed to the bottom.

We try to secure one with the net as it makes its appearance, but its visit is of such short duration, and its movements so rapid, that we do not succeed. Then the thought strikes us that a dash at the bottom may enable us to take it by surprise as it rests. We try it, and with what result? Among the contents of the net we find a number of small insects jumping about by means of long legs that remind us of the oars of *Notonecta*, and which are evidently not adapted for motion on land.

The insects to which we refer are much smaller than *Notonecta*, but the resemblance is at first sight so striking that the casual observer might suppose them to be the young larvæ of that species. But no; they are provided with perfectly formed wings, and must therefore be regarded as the perfect forms of a smaller species. They belong to the family *Corixidæ*, of which nearly thirty species form the typical genus *Corixa*.

When we examine one of the *Corixæ* we find certain points of resemblance between it and *Notonecta*. Its body is somewhat boat-shaped, but instead of being keeled is almost flat on the back. The beak resembles that of the true 'boatmen,' but is considerably shorter in proportion; and the *scutellum*, though present, is not conspicuous, but is covered by an extension of the first thoracic segment.

The front legs are not so well adapted for prehension. The *tarsus* consists of a single long joint, and this is fringed with stiff hairs, so that it becomes useful in helping the insect to swim. The middle legs, which are the longest, are slender, and the tarsus terminates in two long and thin claws. The hind legs, as in *Notonecta*, are long and strong, and are used after the manner of oars; and the tarsus, which in this case consists of two joints, is flattened, and fringed with bristles.

The outer wings are horny with the exception of the tips; and the inner ones, which are membranous, exhibit a beautiful iridescence.

Now let us examine a *Corixa* in its native element, introducing with it, for the sake of comparison, a *Notonecta*. We put them

Fig. 201.—*Corixa Geoffroyi*, ENLARGED

Fig. 202.—*Corixa Geoffroyi*, UNDER SIDE, ENLARGED

into a bottle of clear water, at first without any weed or any other solid object. They both dart about vigorously, and, not being able to distinguish between the colourless glass and the water, dash their hard heads against the former with a force that would be fatal in many other creatures.

At last these efforts to secure a shady corner become less furious, and both the insects resolve on resting. But how different are their modes of swimming, and also their positions of rest!

Notonecta swims on its back, as we have already observed, but the *Corixa* keeps its back uppermost all the time. The former also rests in this same position; and having no object below to which it can anchor itself, has to be satisfied with a position just below the surface, its light body being kept there by the film. But some species of *Corixa* are heavier than their own volume of water, and can remain at the bottom without anchorage.

Having observed these differences, we introduce a little gravel and some aquatic vegetation, and then prepare for further observation. Both creatures are soon anchored below, the *Corixa* almost invariably choosing the very bottom, often indeed hiding itself quite out of sight if possible, but *Notonecta* seeming equally at home at the bottom or in midwater.

Again, we notice that the two insects breathe in very different ways. The *Corixa* does not float to the top without effort, on account of the higher specific gravity of its body; but when it swims to the surface, its body remains stationary for a time with the back uppermost, this part being lighter than the ventral portion, and especially the thoracic region, which contains the stigmata. A film of air extends from these, round the very narrow neck, to the surface of the water, thus forming a communication between the stigmata and the pure atmosphere above. In a moment this air is exchanged for a fresh supply by diffusion, aided by a downward bend of the head, and the creature darts below with this supply between its head and thorax.

Like *Notonecta*, the *Corixæ* generally fly by night, and are attracted by bright lights. They hibernate during the cold weather, burying themselves in mud, or congregating under dead leaves at the bottom of the water; but they resume activity in mild weather, even in the depths of winter, and if kept indoors retain their activity throughout the season, devouring each other if no other food is provided for them.

The eggs are fastened by a glutinous substance to submerged objects, and the larvæ resemble the perfect insects except in the possession of wings.

The species figured (*Corixa Geoffroyi*) is both the largest and the commonest of the typical genus, and may be found in almost every weedy pond. Its colour is a dark brown, but tinted with yellow, the latter tint being due to transverse rows of small yellowish spots on the thorax, as well as to minute yellow hairs scattered irregularly over the elytra. The head is yellow, and the eyes large and black.

These latter characteristics obtain more or less in all the *Corixæ*; but some species of the same family have no yellow markings on the thorax, and in others the scutellum is not hidden by the prothorax.

It may be mentioned in conclusion that the members of this family are so similar in general appearance that it is a difficult matter to distinguish between species; but the mature small species may be readily distinguished from the larvæ of the larger ones by the presence of the wings.

Water Scorpions

These insects are so called because of the peculiar form and action of the front legs, which are used entirely as prehensile organs, and disposed in such a manner as to remind one of the forceps of the scorpions of warmer countries. It must not be assumed, however, that these two creatures—the water scorpion and the true scorpion—are closely related because they are similarly named. The latter is not an insect, but belongs to the same class as spiders and mites, and possesses eight legs; but the former is an insect, with only six legs.

The Water Scorpion (Plate III, figs. 2 and 2A) is one of those insects that are sure to be found in the net of a pond-hunter, unless indeed all his energies are confined to one of those few localities where the commonest and most widely distributed species fail to make their appearance. And once found it is certain to be recognised, for it is the only member of its genus, and there is no other British species for which it can possibly be mistaken.

If any insect forms can rightly be described as ugly, then surely the Water Scorpion (*Nepa cinerea*) must be included under that category, for neither its flat buglike shape nor its dirty mud-brown colour is particularly pleasing to the eye. Yet the creature is certainly a very interesting one, and though not likely to prove attractive at first sight, it has its good points, and may even be made to display a little bright colouring when we have learnt where to look for it.

Its body is broad, flat, and thin, and shaped much like a small leaf; hence it is not always readily recognised in the pond or among the contents of the collector's net. If it rests on aquatic weeds, as it often does, it is easily mistaken for a dead leaf; or if on a muddy bottom, it is hardly to be distinguished from the mud itself, so closely does it resemble the latter in colour. In this position, too, we often find its back covered with a deposit of pond sediment that adds to the difficulty of detection; and this difficulty is still further increased by the general sluggishness of the creature.

So sluggish indeed is the Water Scorpion that it would die of starvation were it not for the agility of the movements of its front prehensile legs. Its resemblance to a dead leaf and the similarity of its colour to that of the mud in which it grovels are of little service as a protection against enemies, for, judging from observations of varied collections of predaceous insects in aquaria, the Water Scorpion is not regarded as a delicate morsel. It is not often attacked by its carnivorous companions, who prefer rather to devour their own species. And this seems wise on their part, for there cannot be much nourishing matter between the two layers of the integument of the flat *Nepa.*

The resemblances referred to, however, are a great help to the insect, for they enable it to lie in wait for its unwary victims without being detected. Thus when on the watch for prey the Water Scorpion remains motionless, being apparently aware of the deficiency of its locomotive powers, and trusting to its deceptive appearance and the alacrity of its front legs. When, however, a hapless victim comes within range the two forcep-like legs close upon it smartly, allowing no hope of escape; while at the same moment the short but sharp beak is thrust into the victim, and the process of suction commenced.

Let us now note a few points in the structure of *Nepa.* The forelegs are very peculiar. They are furnished with sharp claws,

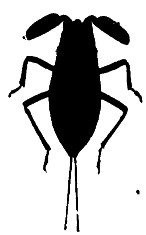


FIG. 203.—*Nepa cinerea* WITH FORELEGS FOLDED

FIG. 204.—FORELEG OF *Nepa,* ENLARGED; SHOWING THE DEEP GROOVE WHICH RECEIVES THE TARSUS

bent inwards; and are so constructed that they can be closely folded after the manner of a pocket knife, one part being deeply grooved in order to receive the other. The other legs are rather slender, and are used for walking only.

The outer wings are horny, with a membranous portion at the tips. They overlap slightly when closed, but the scutellum always remains visible. The under wings are membranous, and rather opaque. They are of a smoky grey-brown colour, with a longitudinal scarlet streak extending from the base to the middle.

It is when the wings are extended that we see the beauty of this insect, for the upper surface of the abdomen is rather richly coloured at the edges with bright red, and this forms a pleasing contrast with the wide patch of black down the middle.

FIG. 205.—*Nepa cinerea* WITH WINGS EXTENDED

The eyes are small, but rendered conspicuous by their intense blackness; and the antennæ are concealed in grooves beneath them.

At the tip of the abdomen is a long and slender filament that closely resembles the ovipositor of some other insects, but it is really a breathing tube, and is in communication with the tracheæ. It is composed of two distinct parts, which may be easily separated by means of a needle. Each half is grooved on the inner side, so that they form a tube when brought together. They are locked together by rows of bristles on the inner edges.

If we watch the insect when it is crawling over pondweeds we often see it walking backwards, with the tail filament directed upwards, until the latter is thrust through the surface film of the water; and in this way it opens up a free communication between the tracheæ and the atmosphere.

The tracheal system consists of two main tubes which run longitudinally along the sides of the body, giving off numerous branches at right angles. These two main tubes terminate in a pair of stigmata at the tip of the abdomen, just at the base of the breathing tube, and are thus brought into communication with the free air.

Nepa appears to require very little air, especially during the cold weather, when it exists in a semi-dormant condition. For hours together it will remain in midwater, attached to pondweeds, without ever approaching the surface. And even during the summer months—the period of its greatest activity, if we may truthfully apply such a word to so sluggish an insect—it will often remain below for a long time together; and yet on the other hand it will often take up a position close to the surface, and stay there for a long time with the tip of its breathing tube just exposed to the air.

During the prolonged intervals spent below, I have reason to believe, the insect is not always deprived of fresh air. I have often seen it walking backwards on weeds, with the tail filament directed obliquely upwards, just as though it were *feeling* for the surface. Now it has often happened on such occasions that the growing weeds, exposed to a good light, supported a number of small bubbles of gas, consisting principally of oxygen; and as soon as the tip of the breathing tube penetrated one of these bubbles the insect ceased to move, being apparently satisfied at finding a temporary supply.

This same feature may be observed more readily if larger bubbles, produced by forcing a fine jet of water into the aquarium, become entangled in the dense filamentous foliage of such a plant as the Hornwort. In this way a number of moderately large bubbles may be easily suspended in the water, and the *Nepa* will soon pierce one as it moves about.

A restless Water Scorpion may be even more easily quieted by entangling a large bubble of air in a small mass of cotton wool which has been lightly oiled, and then presenting it to the extremity of the breathing tube by means of a thin piece of stick.

Water Scorpions hibernate in the perfect state, as has already been hinted. In an indoor aquarium they remain more or less active throughout the winter, except when exposed to extreme cold. Those I have at the present time (middle of January) are kept in a room in which a fire is seldom made; and they remain motionless, as long as they are undisturbed, huddled together in two or three small clusters on the American Pondweed.

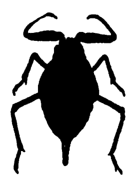


FIG. 206.—LARVA OF *Nepa cinerea*

The eggs are very curious objects. Each one is oval, with seven little hairlike projections, arranged in a circle and forming a small conical cup. They are laid in a continuous string, each egg lying in the cup formed by the filaments of the preceding one. After they are deposited the seven filaments curve backward, forming as many little hooks.

The larva of *Nepa* is very similar to the perfect insect; but its body, though smaller, is not so thin and flat. Two little swellings at the side of the thorax mark the position of the rudimentary wings. It is further distinguished by the absence of the slender breathing tube, instead of which it has a thick, short, and bluntly pointed projection at the tip of the abdomen.

The insect is aquatic throughout the whole of its existence.

Ranatra linearis

There is another insect that is popularly known by the name of Water Scorpion; but, as will be seen by its name just given, it belongs to another genus. Like *Nepa cinerea*, it is the only British member of its genus.

FIG. 207.—*Ranatra linearis*

At first sight it seems to form a marked contrast to the last species, for its body is very long and slender; and instead of being flat, as is generally the case with bugs, is cylindrical. The colour is also much darker, being of a very deep ashy brown, almost black in fact.

The head is small, and the eyes, though small, are prominent and conspicuous. The beak is short and sharp. It is curved downwards when not in use, but directed forward when the insect is preparing to attack.

This insect is hardly to be described as active, but is certainly more so than *Nepa*; for not only does it display considerable agility when in pursuit of its prey, but will also boldly defend itself when in danger. It will fearlessly attack any creature that affronts it, and will close its pincerlike forelegs on any object thrust in its path.

The forelegs are very long and slender, and are used solely as prehensile organs. The basal joint, which is usually very short in insects, is in this case much elongated. The femur also is very long. It is also curved, and bears a toothlike projection beyond the middle. The portion beyond the tooth is grooved like the femur of

Nepa, in order that it may receive the tibia and tarsus when these are not required for raptorial or defensive purposes. It will be seen, too, that the tibia and the tarsus together form a sickle-shaped and sharply pointed portion, admirably adapted for its deadly purpose.

One would hardly imagine that an insect with such a slender sticklike body could possess two pairs of wings; yet such is the case. The outer pair are of a horny nature, excepting a small membranous portion at the tips; and they are so narrow that they meet in the middle of the abdomen without any overlapping except in the narrow membranous portions. The hind wings are wider, and form the real organs of flight. They are exceedingly delicate and transparent, and are neatly folded beneath the outer pair when not in use.

Like the last species, *Ranatra* delights in grovelling in mud and in clambering on pondweeds, now and then coming near the surface and thrusting its long breathing filament into the air.

When taken in a pond net, it is often so sluggish in its movements that it may be easily mistaken for a piece of stick, and it frequently makes little or no endeavour to free itself from the mud and weed that have been dredged in with it. When, however, it attempts to walk, it covers ground much more rapidly than its brother scorpion, and it often elevates its body to such an extent on its long and slender legs as to suggest the idea of a creature on stilts. The position of the forelegs, too, is very characteristic. They are elevated above the body in such a manner as to add to the menacing attitude of the insect.

Its mode of walking is also peculiar, for it moves its second legs forward, one after the other, while the hind legs remain stationary, and then pulls up both hind legs while the others retain hold. Thus it progresses by means of a series of long strides, using each pair of walking legs almost as one.

Ranatra is easily kept alive in the aquarium, providing it is supplied with food; and, as to this, it is not particularly dainty. It will attack small fishes, worms, freshwater shrimps, and almost any kind of insect larva. It lies in wait on the mud or, more generally, among weeds, with its raptorial forelegs in position for the attack; and so nimble are the movements of these seizing organs that it often succeeds in securing creatures that move rapidly in the water.

Occasionally it will take to flight; and when it alights upon the water, or when placed on the water after having been removed, it has some little difficulty in getting below, on account of its extreme lightness, and partly on account of the fact that its body does not become wetted. As it thrusts itself into the water the surface film is forced down all around it, so that, for the time, it lies in a little hollow.

The eggs of *Ranatra* are laid singly on submerged objects. Each egg has two hairlike filaments, but these do not clasp the succeeding one as in the case of *Nepa.*

The larva is similar to the adult in general form, but it has no long breathing tube, and of course no wings.

Ranatra is not an uncommon insect, but it is not nearly so plentiful as *Nepa.*

Naucoris

We shall briefly note one other Water Bug—a species called *Naucoris cimicoides*, which is sometimes included in the same family as *Nepa* and *Ranatra*, but sometimes placed in a separate group.

Its body is oval, slightly pointed at the tip, and broad and depressed, but not nearly so flat as *Nepa.* The upper surface is convex, and completely covered by the outer wings, with the exception of a very narrow margin on each side.

FIG. 208. — *Naucoris cimicoides*

This insect is not so widely distributed as the other Water Bugs we have mentioned, but is extremely common in some parts. In many ponds indeed it actually swarms, and several specimens may be taken at almost every dip.

Its habits are like those of *Notonecta* in some respects. It swims by means of its long and fringed hind legs, using them after the manner of oars, and proceeding with a vigorous but jerky motion.

It spends most of its time at or near the bottom, where it anchors itself by its front legs to the pondweeds; but it comes to the surface at frequent intervals to renew its air supply, and this respiratory movement is carried out much in the same way as in *Notonecta.*

The middle legs of *Naucoris* are rather long, but very slender, and of little use for swimming. The forelegs are very short, and used for prehension only. They are provided with long and sharp claws, and are exceedingly powerful in comparison with their size, the femur being of a globular form, thus accommodating the well-developed muscles which enable the creature to seize and hold its prey.

Like *Notonecta glauca*, *Naucoris* flies well, but usually employs this means of locomotion during the hours of evening twilight alone. If kept in an indoor aquarium it will frequently fly freely about the apartment in which it is kept, and, like moths, is attracted by artificial lights.

Its outer wings are stiff, and serve more for protection than for flying; but the hind wings are exceedingly delicate in structure, and exhibit a most beautiful display of iridescent colouring.

FIG. 209.—*Naucoris* WITH WINGS EXTENDED

FIG. 210.—HEAD OF *Naucoris*, SHOWING THE BEAK, ENLARGED

The beak is exceedingly sharp, and is directed backward between the bases of the forelegs. The latter are usually directed forwards, but in our engraving the left one is turned out of its natural position in order to show the whole of the beak, which would otherwise have been hidden from view. The pain produced when the beak pierces one's skin is intense, but it lasts for a very short time.

AQUATIC SPRINGTAILS

We have next to deal with some very small insects belonging to the order *Thysanura*. Most of the species are terrestrial, and live under the cover of stones, leaves, and other objects in dark and damp places, and hop about by means of filaments which are bent under the abdomen. This latter feature has earned for them the popular name of Springtails.

There are a few aquatic species, the commonest of which—the Common Water Springtail (*Podura aquatica*)—may be taken as a type of the group.

If we examine the surface of water in ditches and at the margins of ponds we may often meet with black patches that look like collections of floating dust. Thrust the end of a stick into one of these clusters, and immediately the particles disperse. Remove the stick and watch steadily, and they are seen to collect again.

These movements are mysterious when viewed at a distance of a few feet; but when we look more closely we find that each of the black particles is really a little animal that leaps about actively on the surface film.

It is not an easy matter as a rule to watch the movements of these creatures in the field; but they do well in an aquarium, and it will repay one to secure a number of them for observation at home.

They may be easily taken in this manner: Gently push a wide-mouthed bottle into the water close beside a cluster of the creatures, holding it a little obliquely with the mouth uppermost. As soon as the lower part of the rim of the bottle passes below the surface, the surface water will flow into the vessel, carrying the floating insects along with it.

This is the most convenient method of securing them when they are required isolated from other forms of pond life. A preferable plan, in my opinion, is to make a dash at cluster after cluster with a small pond-net, and then transfer the contents of the net, weeds and all, to a small bait-can.

When you return, throw all into a moderately large vessel of water—a glass aquarium or an earthenware pan—and you will soon see the little creatures, rather less than a line in length, collecting on the surface of the water. Some also will attach themselves to the sides of the vessel.

Whenever they are disturbed, either by tapping the vessel, touching the water, suddenly throwing a strong light on them, or by any other means, the scene becomes a very lively one. The clusters break up, and those round the sides skip about, jumping from the water to the sides of the vessel, and then back again to the water, but soon becoming steady again when the disturbance is over.

But even then they are by no means motionless, for, though the clusters do not change much in appearance, the little insects are almost continuously on the move.

We now remove one of them for examination under a magnifier. A camel-hair brush is moistened slightly between the lips and then pressed gently on the animal's back. It will adhere slightly, and may be quickly transferred to a small cell on a glass slip and covered with a cover glass. This must be done quickly, or the *Podura* will soon recover its feet, and then leap off the brush with a powerful movement of the bristles which form the 'spring-tail.'

Having captured the insect in this way, we study it with a powerful hand magnifier, or, better still, by means of the low power of a compound microscope.

Now we see that it is really an insect, for it has six pairs of legs. The segments of the body are also very distinct, but there is no constriction dividing the thorax from the abdomen. In fact the body is thick and clumsy, cylindrical in form, but tapering slightly towards the tip of the abdomen.

The body appears quite black in a moderate light, but when more strongly illuminated it is seen to be of a bluish colour. It is so opaque, too, that it is of no use reflecting light from below it; but it is best viewed when a strong light is thrown down on it by means of a condensing lens.

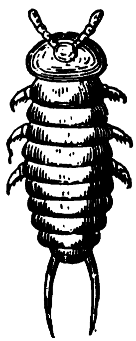


FIG. 211.—*Podura aquatica*, MAGNIFIED × 25

The antennæ, like the body itself, are thick and clumsy. The legs are reddish, and short and thick. They are provided with stiff hairs, and terminate in a single sharp claw. The mouth is not suctorial, like that of the *Hemiptera*, but is provided with jaws for chewing solid food.

Podura has no wings in the adult state, and undergoes no metamorphoses; hence the adult is to be distinguished from the earlier stages only by its size.

If captured before they are fully grown, and then kept under observation in the aquarium, specimens of a much lighter colour than the others may often be seen. These have just undergone a moult, and thus appear in their new dress, which turns darker shortly afterwards. Where a large number are kept we may also observe the cast skins floating on the surface of the water.

It will be necessary to turn the *Podura* on its side or its back in order to see the springing apparatus. This consists of a prolongation of the abdomen in the form of a forked appendage bent under the body. When the insect leaps, this appendage is forcibly extended, so that it strikes against the surface film of the water, or against the solid object on which it happens to be stationed, thus lifting the body into the air.

The length of the leap varies from one to three or four inches—that is, from about twelve to fifty times the length of the body. It seems surprising that the surface film should be capable of resisting the sudden pressure necessary to lift the fat and bulky body of *Podura* with such force and yet remain unbroken. Yet such is the case.

When the insect alights, too, the film resists the blow so effectually that it is not broken, and the *Podura* is therefore never wetted during the contact. And even if the film were to break and the creature become more or less submerged, still it would not be wetted, for the body is covered with short close hairs which prevent the water from coming in contact with it; and thus the submerged *Podura* would be covered with a thin layer of air entangled between the hairs.

Although the insect displays so much agility when leaping about, yet it is probably at this time that it appears at its worst. It is eminently superior to the cat in leaping powers, but it might learn much from that animal as to how it should fall. The *Podura* is as likely to fall on its back as on its feet, and when it does so, it scrambles about in a most awkward manner in order to gain its footing. It is only fair to mention, however, that this awkwardness is far more apparent when the insect has been removed from its natural habitation—when placed, for example, on a sheet of paper. On the other hand, *Podura* seems to be able to walk far better on a solid substance than on the surface film of water. The latter, though unbroken by its claws, seems to give way behind it when it tries to thrust its body forward.

Podura is essentially a creature of the surface, but it evidently descends into the water sometimes. It appears to have no power to penetrate the surface film except by walking down the stems of water weeds, or down the banks of the pond or ditch in which it lives. In this way it can make use of its legs and claws to overcome the resistance offered to its progress.

The *Podura* is so small that the young pond-hunter may have no desire to preserve specimens for his collection. As a rule it is to be readily obtained through the greater part of the year, and therefore there is no need to set by specimens for examination. Again, a colony of these insects, once deposited in an aquarium, will establish themselves and give rise to successive generations year after year.

Should the reader, however, desire to preserve *Podura*, he must give up all idea of *dry* preservation, for the body of the insect soon shrivels to a shapeless mass. I have found specimens keep well in a small tube of diluted alcohol; but where the necessary knowledge and skill are possessed, they should be preserved as microscopic objects.

Aquatic Neuroptera

The *Neuroptera* is such a varied group of insects that it is impossible to name many features common to all; and this difficulty is further increased by the great difference of opinion as to the extent of the order. They all agree, however, in the characteristic intended to be expressed by the word *neuroptera*, which signifies 'nerve-winged;' for in all of them the wings are divided into a large number of spaces by a delicate network of nervures.

The wings are four in number, and both pairs are similar in structure, consisting of a very thin and transparent membrane. They are also nearly equal in length, and are seldom folded; nor do the foremost pair cover the others as in the winged species previously described.

The subdivisions of the order vary considerably in their metamorphoses. Some pass through a quiescent pupal stage, while others are active and predaceous throughout their existence.

The aquatic insects of this order include Dragon Flies, May Flies, and Stone Flies.

Dragon Flies (*Odonata*)

These insects, at least the commonest of them, are well known to every lover of the country, for they are to be seen flying in the neighbourhood of ponds and streams almost everywhere during the summer months. But though so well known in the perfect state, it is doubtful whether many of my readers are acquainted with their whole life history and their habits at different stages of their existence. In fact there is yet much to be learnt concerning many of the British species, which number nearly fifty, even by experienced entomologists; for the rarer species, and even some of the more common, are as yet imperfectly known in their larval and pupal states.

Although there are marked differences in the form and colouring

FIG. 212.—AQUATIC INSECTS

1, *Ephemera vulgata*; 2, *Ephemera* larva; 3, *Platetrum depressum*; 3a, *P. depressum* emerging from pupa case; 4, *P. depressum*, larva; 5, *Calopteryx virgo*; 6, *Agrion minium*; 7, *Phryganea grandis*; 8, *Phryganea*, larva cases of the various species, yet, as far as their habits and life histories are concerned, they may be divided into two groups, so that a general description of a chosen type of each will answer equally well for the others.

We will first note the chief characteristics of the perfect insects, and then speak of the earlier stages.

The bodies of Dragon Flies are generally very long, slender, and cylindrical, but in some species they are shorter, broader, and much flattened. In the former case the number of segments is the same as in the latter; in fact the segments are so long in some species that the abdomen presents a number of obtuse angles when curved under.

Some species lay their eggs on the stems and leaves of water plants a little below the surface, and the long bodies are of service here in allowing the operation to be performed without danger of getting the thorax and wings wet.

The thorax is always broader than the abdomen, and, especially in the slender-bodied species, is very deep from dorsal to ventral surface, in order to accommodate the powerful muscles that move the wings.

The head is large in proportion to the size of the body, but it will be seen that the bulk of it consists of the eyes, which are not only large and prominent, but so formed and disposed as to give the creature a very wide range of vision. These organs too are generally most gorgeously coloured. The outer surface is highly polished, and though apparently perfectly smooth when viewed with the naked eye, may be seen to be regularly honeycombed when more minutely examined.

Each little hexagonal area is a facet of one of the divisions of the compound structure, and the whole outer structure is so transparent that we can look into the interior and often witness a grand display of brilliant colour, changing from one hue to another as we alter the angle at which we view it. In some species the eyes are nearly spherical, and situated at the sides of the head, with a considerable space intervening; but in others they meet in the middle line above, looking like one continuous organ, and almost completely hiding the other parts of the head when viewed from that side.

In addition to these large compound eyes, Dragon Flies possess three simple eyes or *ocelli*, which are arranged in a row or form a triangle on the front of the head. A pair of small antennæ also arise from the inner edges of the former.

It will be imagined from the above remarks that Dragon Flies are especially gifted creatures as far as visual organs are concerned, and as to their efficacy, no one who has ever watched one of these insects on the look-out for flies can have any doubt. It will make straight for an insect some distance off, and never fail to catch its victim, so sharp is its vision and so powerful its wings.

The mouth of the Dragon Fly is a very complicated structure. If we look at it when the insect is not feeding, it appears to have no biting jaws; but poke a small stick or a piece of straw against the front of the creature's head, and it will begin at once to bite away savagely at the intruding substance, thus enabling us to observe the different parts of its mouth.

At first sight it appears to possess jaws that move vertically, like those of vertebrate animals, but a closer inspection will prove that this is not the case. The parts referred to are really the lips, and when these are brought together, the true jaws are quite concealed beneath them. Then, while the insect is chewing, the large flat lips are kept continuously moving up and down, thus giving the false impression just mentioned. However, the true jaws—both maxillæ and mandibles—are easily seen behind the lips. They are strong and powerful, armed with toothlike processes, and work horizontally as in all other chewing insects.

While thus engaged in tantalising the vicious Dragon Fly in order to make it display its jaws, we can hardly fail to notice the extreme slenderness of the neck, for the slightest pressure on the head is sufficient to make it rotate on the thorax; and if the top of the head be tilted forward, we see the neck itself, so narrow and threadlike that it would appear quite inadequate to support such a massive head.

In carrying out these observations we shall probably hold the Dragon Fly between the finger and thumb, either grasping the thick and firm thorax, or else pressing the wings together over the body. In either case the insect may curl its abdomen below and forward in a most menacing manner, just as a wasp or a hornet would under the same circumstances; and the movement is so suggestive of these hymenopterous insects that an inexperienced person would instinctively avoid contact with the tip of the body for fear of being stung. In fact it is probable that few, having caught a Dragon Fly for the first time, would have the nerve to retain it a moment after observing such a threatening attitude, unless previously advised of the total absence of anything in the form of a stinging apparatus.

It may be mentioned, too, that the tip of the abdomen often terminates in one or more sharp appendages, which add still more to the menacing appearance of the insect when the above attitude is assumed, for such appendages may be mistaken for stings by those who are not acquainted with the true nature of these organs.

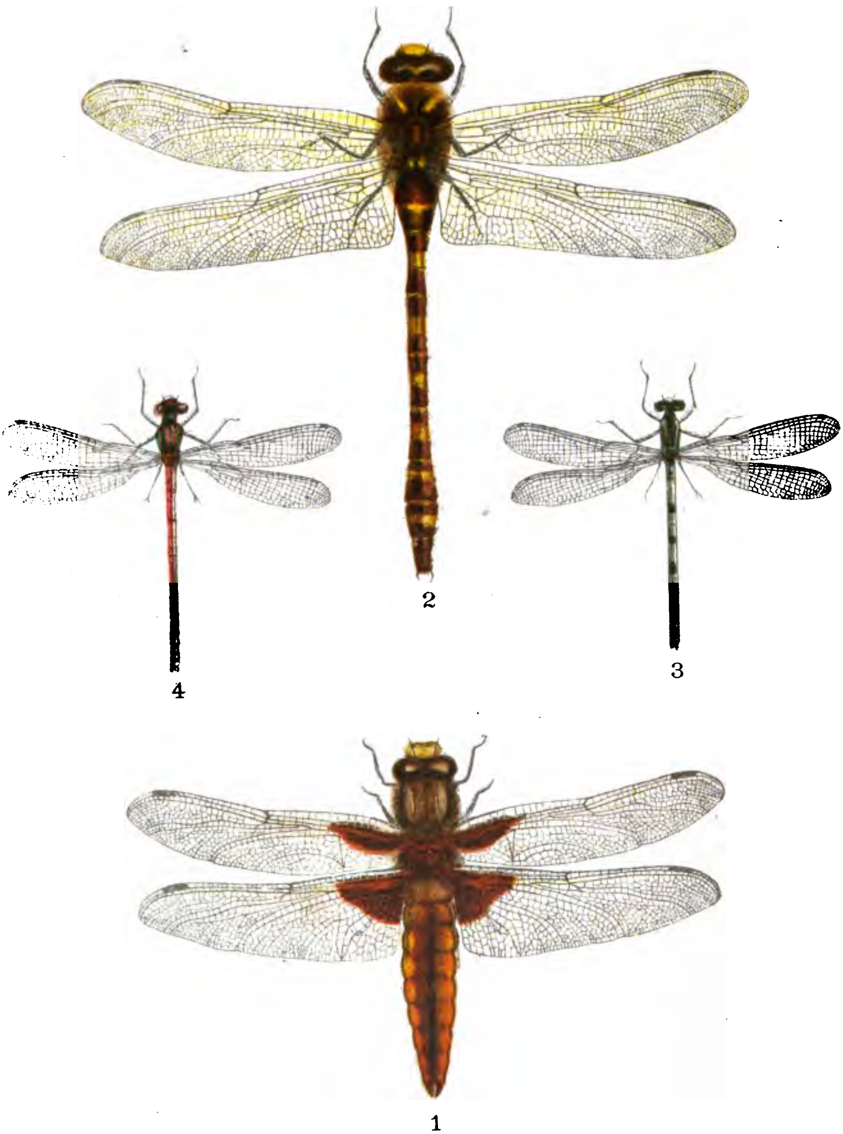
I have mentioned the beautiful colours displayed in the large eyes of Dragon Flies, but equally brilliant hues are often reflected by other parts of the body. Thus, the thorax and abdomen are frequently most gorgeously tinted, the surface often giving brilliant metallic reflections. But these, though a source of great pleasure to observers of the living insects, are a cause of much disappointment to those who preserve the insects for the cabinet. In nearly every case these beautiful colours fade away to ugly yellows and browns, and sometimes change to black, the changes taking place soon after the insects are dead.

There is no known method of preserving the beautiful colours of these insects, but those of the abdomen may be in part maintained by the removal of the contents. There seems to be no doubt that the loss of brilliancy is due greatly, if not entirely, to decomposition; and this may be reduced considerably by slitting down the abdomen along the under side and thoroughly clearing it of all its internal parts. This is no easy task in the case of the small slender-bodied species, but should invariably be carried out with the larger specimens preserved.

Another source of trouble to the collector of Dragon Flies is the extreme brittleness of the slender abdomens and of the narrow necks when the insects are dry; but the only remedy here is care and delicacy in handling the specimens, and also in avoiding anything in the way of violent shocks, such as might be produced by the careless depositing of a store box, or the sudden closing of a drawer in the cabinet. Of course the detached portions of a dried insect can be easily replaced by the aid of a little coaguline or a suitable gum; but it is far better to take pains to study the prevention rather than the cure.

The wing of a Dragon Fly generally consists of an exceedingly thin and transparent membrane, and in some species this is deeply and beautifully coloured. The principal nervures run from the base to the tip of the wing, or curve round towards the hind margin. Along the front margin the nervures with their branches are so disposed as to form small square spaces or 'cells,' and in some of the small species the whole area of the wing is similarly divided up

PLATE IV.



West, Newman imp.

into square spaces [illegible] much smaller tow[ard] [illegible] have from four to [illegible] there is usually a [illegible] passes backward. [illegible] a dark spot called the [illegible] and often sharply [illegible] or represented by a [illegible]

In nearly all, the [illegible] surfaces, which give a very [illegible] the air. In [illegible] so thin and transparent that [illegible] the insects are flying were it not [illegible] by their bright membranes, [illegible] the slender body, floating [illegible]

Let us [illegible] a scored [illegible] points, whose [illegible]

[illegible] *Platetrum* [illegible] of water that [illegible]

Here [illegible] glen, [illegible] twelve or [illegible] journey [illegible] makes a sudden [illegible] or the [illegible] insect that comes [illegible] track.

[illegible] a similar [illegible] confining [illegible]

We [illegible] of the [illegible] them, and [illegible] some [illegible] continues [illegible] in the [illegible] our presence [illegible] or perhaps [illegible]

Now a [illegible] Dragon Fly, with one [illegible] its powerful jaws, and [illegible] a wing, which has been [illegible] like a [illegible] leaf

PLATE II

West, New

into square spaces; but in some species the reticulations become much smaller towards the tip and the hind margin, and the spaces have from four to six sides. Near the front margin of each wing there is usually a slight bend, from which a short but strong nervure passes backward. Also, near the tip of each wing there is generally a dark spot called the stigma, sometimes elongated, sometimes short, and often sharply rhomboidal. In some species the stigma is absent, or represented by a *pale* spot.

In nearly all, the wings have polished and glistening surfaces, which give a very pretty effect when the insects flit or sweep through the air. In some of the small species the wings are so thin and transparent that they would not be visible when the insects are flying were it not for the flashes of sunlight reflected by their bright membranes, and nothing would be observable except the slender body, floating like a thread wafted through the air.

Let us now repair to the haunts of the Dragon Fly. We choose a scorching summer's day, and journey to some spot where isolated ponds, whose banks are overgrown with semi-aquatic vegetation, are distributed in the neighbourhood of a sluggish stream.

Before we reach the water we probably meet with a few of the larger species, such as *Cordulegaster annulatus*, or the broad-bodied *Platetrum depressum*, which often wander far from the patch of water that formed their home in search of food.

Here is one sailing backwards and forwards in a small wooded glen, confining itself strictly to one little district not more than twelve or twenty yards long, and following the same course as it journeys to and fro, except when it makes a sudden dart to the right or the left to pounce on some hapless insect that comes too near its track.

Yonder we see another, engaged in a similar manner, and also confining itself to its own chosen area.

We stand quite still, just in the middle of the course of one of them, and carefully watch its movements. For some time it continues sailing up and down its track, its powerful wings never tiring in the rapid flight; and so fearless is it, that it takes no notice of our presence, and even darts within a foot of us out of sheer bravado or perhaps inquisitiveness.

Now a butterfly flits across its sacred track; and the Dragon Fly, with one steady but rapid dart, seizes the creature in its powerful jaws, and continues its flight as before. Then down falls a wing, which has been clipped from the butterfly's body, like a faded leaf on the moss below. Then another and another, till, in the space of a few seconds, the Dragon Fly is feasting in the air on the wingless trunk.

At last the voracious insect settles on a twig, and we approach it stealthily, net in hand, feeling confident that now is *its* turn to become a victim. We find it quite motionless on its perch, and prepare to strike; but just then we hear a short rustling sound, like the sudden shaking of a single leaf, and the Dragon Fly has disappeared. Its powerful wings had rustled against a leaf as it started into the air, and its first dart was so rapid that we missed the direction.

But it has not gone far. Here it is, in the same beaten track, and now it alights again on the selfsame twig, apparently gazing on its enemies at close quarters in pure defiance! We strike, but miss our aim; and the creature seems more defiant than ever, or it flies past us two or three times, approaching dangerously within range, and then settles again almost within arm's reach.

Another stroke of the net, and we have it! Its long wings lose their freedom in the folds of the net, and so we secure it easily between the finger and thumb, and transfer it to a dark box in which it remains quiet, having lost the stimulus provided by the scorching sun.

Now we approach a large pond the banks of which are overgrown with flags and rushes. Here we see scores of smaller and more delicate creatures resting on the leaves, but starting off with a more feeble flight as we approach them, and soon settling again just a few yards ahead. These are easily taken in the net, often three or four at one stroke, though many of them move to a safe resting place on the rushes beyond our reach.

The scene is a very interesting one, for although these species are too small to give any display of brilliant colours at a distance, yet their glittering wings, airy flight, and floating threadlike bodies have a very pleasing effect, especially when they appear in profusion, as they often do, round the banks of ponds.

But what a change when the shadow of a passing cloud sweeps over the field! Not a single Dragon Fly is now to be seen on the wing; but a careful search among the flags will reveal them at rest, with their wings folded together just over their slender bodies. And, having lost the stimulating power of the sun's rays, they have, almost in a moment, become so sluggish and unwary that they may be removed from their resting places by taking the wings between the finger and thumb. But this period of lethargy is over as soon as the shadow has passed and the bright rays again strike the pond.

In addition to these small and fragile species we shall probably see one or two of a larger and sturdier build, flying gracefully but swiftly forwards and backwards along the line of rushes, restricting themselves each to the same limited beat, and seldom swerving from the chosen path except to pounce on a passing insect. One has to wield the net with great vigour to catch these powerful fliers, and they often evade all our attempts by keeping over the water just beyond our reach.

We next stroll beside a sluggish brook the banks of which are overhung with the boughs of bushes and the foliage of tall, herbaceous plants. Here our attention is attracted by a cluster of rather large insects that much resemble the Dragon Flies we have already seen in general form, but their wings are deeply coloured; and, instead of isolating themselves and flying rapidly forwards and backwards within a limited range, they sport about in the same little nook, something after the manner of gnats.

Having now observed a few of the most striking features in the structure and habits of Dragon Flies, we will briefly study the earlier stages and metamorphoses. We have seen that the perfect insects are not aquatic in the true sense of the term—that is, they do not live *in* the water, but hover over or near it. But the term of the imago is short compared with the total life, for nine or ten months are occupied in the preparatory stages; and as the whole of this time is spent in water, we must regard the study of the insect as a necessary part of the work of the student of aquatic life.

As soon as the young larvæ are hatched, they find their way to the bottom of the water, and there they remain, grovelling in the mud and climbing on the low-lying weeds, till they are fully grown in the following summer.

During their development they undergo a series of moultings, but they never change much in form till the final transformation, when the perfect insects emerge from the pupal skins. The wings begin to appear at an early age, and the development of the insects is so gradual, and the habits remain so constant throughout the whole of the truly aquatic existence, that we have no well-defined pupal stage.

Throughout the summer months, and in fact through nearly the whole of the year, the larvæ may be dredged out with the mud and bottom weeds of nearly every pond and sluggish stream.

Among them we notice two distinct kinds, one with broad and flattened bodies, and the other slender and fragile, with three flattened appendages at the tip of the abdomen. The former are the larvæ of the large and powerful species, forming the families *Æschnidæ* and *Libellulidæ*, and the latter are those of the small and slender *Agrionidæ*. Both seem to delight in grovelling in the dirtiest mud, and thrive well in stagnant ponds, the offensive odours from which would repel any one other than the enthusiastic entomologist.

We will describe the broad larva first. Its body is of a dirty grey colour, so closely resembling that of the mud on which it lives that it can lie unseen at the bottom, safe from its enemies, and a hidden danger to the weaker and less destructive inhabitants of the water. The surface of its body is very irregular, and generally covered with a deposit of mud, which would of course add to the difficulties of detection by those who would either attack or avoid it.

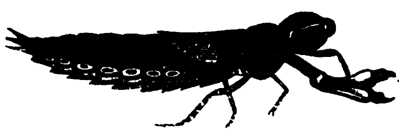


FIG. 213.—LARVA OF DRAGON FLY, WITH 'MASK' EXTENDED

Its form, as well as its colour, might be rightly described as ugly. The broad abdomen, which is widest just behind the middle, is very distinctly segmented, and terminates behind in thick but sharp spines. The thorax bears six strong, spiny, sprawling legs, and rudimentary wings.

The head is a very strange structure. It is big and broad, with two short antennæ, and two prominent eyes at the sides. It is the mouth, however, that is most attractive from a structural point of view. If we look at it from the front we see no jaws, for the same reason that we cannot see them in the perfect insect, except that in the present instance they are hidden behind a single lip, and not behind two which move vertically and meet at their edges.

The lip referred to is the lower, or *labrum*, which is here developed to such an extent that it quite covers the front of the head, and is therefore commonly known as the 'mask.' But it is more than a simple covering for the face, for it is developed into a long, jointed organ by which the insect seizes his prey.

In order to make out its structure we must push down the part that forms the mask proper, and then straighten out the lip, this being easily accomplished by means of a stout needle. Now we see that it consists of a long basal joint that is folded backward under the thorax when the organ is not in use; also another part bending forward, and widened and thickened in front, where it forms moveable joints with the mask.

As to the mask itself, it consists of two distinct parts, arranged side by side, and capable of two distinct movements. They can be brought down from the face, so as to be in a line with the next joint; and can also be moved laterally, just like a pair of jaws. And they *are* virtually a pair of jaws, and the whole lip is used as a prehensile organ, by means of which the larva seizes its prey.

Those who would like to witness the movements of this peculiar appendage should secure a few of the larvæ in question, and place them in a shallow aquarium where their habits may be observed from above, a side view being often unsatisfactory in the case of a creature that grovels in the mud. And it may be mentioned, by the way, that the larvæ of Dragon Flies are not at all difficult to rear if a little attention be given to their requirements. Put them into a shallow pan or glass tank, together with the pond dredgings taken in the net at the same time—mud and all, always including a little vegetation. The mud will soon settle to the bottom, forming just the kind of bed that the creatures like. Then keep them supplied with aquatic larvæ, small worms and fishes, *any* living creatures, in fact, not too large to be disposed of by the voracious foes. There should be no difficulty in rearing the creatures till they assume the perfect state; and in an indoor aquarium they will remain more or less active all through the winter.

But to return to our study. Introduce a few aquatic larvæ, and if the Dragon Fly larvæ have not recently partaken of a meal, you may watch with great hopes of being able to witness a scene.

The Dragon Fly larva is so sluggish and clumsy in its movements, at least as far as the legs are concerned, that it could never succeed in catching very active creatures if it depended on these alone. But it is seldom seen on the chase. It prefers lying in wait with all the stealthiness of a cat, remaining quite still, and often half buried in its muddy bed, thus awaiting its opportunity to strike.

Should an unfortunate creature pass within range, the mask is straightened out with surprising agility, and at the same moment the pseudo-jaws grasp the victim with such power that escape is hopeless. Immediately the mask is retracted, thus bringing the prey quite close to the mouth, and it is then rapidly devoured by the aid of the true jaws, which are quite concealed behind the mask when the latter is closed.

It may be observed that the 'jaws' which form the mask proper (these 'jaws' being the part of the lip that covers the face) vary in form in different species. In the *Libellulidæ* they are broad tri-

FIG. 214.—MASK OF THE DRAGON FLY LARVA (*Libellula*) AS SEEN FROM THE SIDE WHEN ONLY PARTIALLY EXTENDED, ENLARGED

FIG. 215.—THE SAME VIEWED FROM ABOVE

angular plates, hinged at the apices, and toothed like a saw at the bases. They are also concave above (when the mask is extended), and form, together with a concavity in the fore portion of the joint to which they are fixed, a deep basin-like cavity, into which the whole lower part of the head fits closely. When the 'jaws' are thus closed over the face, the sawlike teeth fit so nicely into one another that the division is hardly observable. These teeth, too, it need hardly be added, serve to hold the prey firmly while the true jaws are performing their task.

In other species the mask jaws are narrow and pointed—sickle-shaped, and more like claws in appearance, and consequently do not form such a complete covering for the face.

If we touch one of these larvæ when at rest, we shall observe that it moves away from us with a sudden dart, sometimes without the slightest movement on the part of its legs, just as though it were urged forward by a propelling force acting behind. This in itself is very puzzling, but a careful observation will reveal other movements, evidently connected with this one, simultaneous with it, which will furnish a clue to the mystery.

It will be seen that the abdomen is suddenly compressed just at the moment when the larva darts forward, also that any particles of mud or fine sand that happen to be close behind it at the time are thrust *backward*. Also, during the intervals between the spasmodic movements of the insect we may discern a gradual dilatation of the abdomen, and even detect, by careful observation of small particles suspended in the water, that a current is flowing into the creature's body through an aperture at the tip of the abdomen.

This solves the whole problem. When the abdomen dilates, water flows in through the anal orifice, filling up the enlarged rectum or hindermost portion of the digestive tube. Then, when the insect is annoyed or threatened, it suddenly compresses its abdomen by means of strong muscles, thus forcibly ejecting the water, and the recoil or reaction urges the body forward, the principle involved being exactly the same as that by which we explain the kicking of a gun or the turning of a revolving water-spray.

But now let us watch the larva as it rests unmolested. The abdomen is still pulsating, but slowly, and sometimes at rather long intervals. The introduction of a very small quantity of a soluble colouring matter, or of a solution of some pigment—which should be placed in the right position, just behind the insect, by means of the dipping tube—will show that water currents are passing gently in and out of the body.

Again, if we watch the extremity of the abdomen while these pulsations are in progress we may see the orifice opening or closing as occasion requires. Around the opening are five thick spines, three of which are much larger than the other two. Each time the abdomen dilates, the spines turn away from the opening, and the valvular flaps which guard it separate, thus allowing the current to enter freely. And then follows the muscular contraction by which the water is expelled, in this case slowly and gently, producing no motion of the body as a whole.

Now what can be the object of this movement of water to and from the interior of the abdomen? This question is answered by a careful examination of the walls of the cavity, aided by a low magnifying power.

In the first place we may mention that the larva does not come to the surface for air, but lives entirely at the bottom of the pond; and hence it is clear that it must derive all the air it requires for respiratory purposes from the water. Then, when we examine the structure of the creature, and especially that of its tracheal system, we find this conclusion confirmed; for although the tracheal system is well developed, there are no open stigmata at the surface of the body, and hence all the air that enters the tracheal tubes must pass from the water through their walls.

The walls of the rectum are drawn up into several folds, thus increasing the area of the membrane that lines it. Then round this membrane there are a large number of small tracheal tubes, which are in communication with two main tracheæ that run longitudinally through the body, one on either side. Again, a number of other tubes branch from these two and penetrate every part of the body. Thus the whole tracheal system is brought into communication with the water cavity of the abdomen.

When water is taken into the rectum, some of the oxygen it contains in solution passes through the thin walls of this cavity, and also through the walls of the small air tubes that ramify on its surface. This oxygen diffuses through the tracheal vessels of every part of the body, and the carbonic acid gas that collects in the air tubes passes into the rectum for expulsion.

The larvæ of the *Agrionidæ*, to which we have already briefly referred as being of slender build, are not by any means so ugly as those we have just described. In fact they are comparatively pretty and graceful. Their bodies are often delicately tinted, and taper gradually towards the 'tail,' which is ornamented by three transparent leaflike plates.

These creatures are also much more active than the broad-bodied species, sometimes walking about nimbly by means of their six slender legs, and also swimming at times by vigorous undulations of the body. In the latter case the appendages of the abdomen are a great assistance. They are in fact the swimming organs, and serve the same purpose as the tails of fishes.

The chief function of these appendages, however, is respiratory, and their value as organs of locomotion must be regarded as of secondary importance.

The larvæ in question do not take water into their bodies as the others do, but the dissolved oxygen is absorbed, and carbonic acid gas discharged, through the walls of fine tracheal tubes that are thickly distributed in the thin plates. And, as with the larger larvæ, these tubes communicate with the tracheal system, which sends its ramifications to all parts of the body.

The pupæ of Dragon Flies are as voracious as the larvæ, and, as before stated, differ but little in habits and structure from the latter, except that the wings are more conspicuous.

When the time approaches for the final change, the insects may often be seen climbing the pondweeds, and resting at the surface of the water. Their stigmata are now becoming functional to a certain extent, and they are no longer entirely dependent on the dissolved oxygen of the water.

At this stage the insects should be watched at frequent intervals by those who would like to observe the very interesting final metamorphosis. Of course there is a possibility of witnessing this in the field; but one might search for a long time round the bank of a pond, even where Dragon Flies are very plentiful, without seeing a single insect just at the right moment. I have had this opportunity myself on a few occasions, but have always found it more convenient to watch them in captivity; and then, after one has had the insects under observation for some time, one knows when to expect the interesting event.

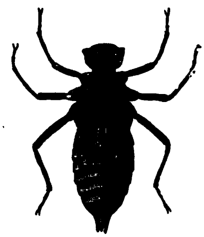


Fig. 216.—Pupa of Dragon Fly

Let us suppose, then, that we have some pupæ in our aquarium that appear ready for their final moult. We must see that they are supplied with a suitable resting place out of the water. This may be provided in several ways. You may obtain some semi-aquatic plant, tall enough to stand well out of the water of the aquarium. Plant this in a flowerpot of soil, and stand it in the middle. If a suitable plant is not readily obtainable, one of the truly aquatic plants that happens to be in the aquarium may be raised a little, so that a portion of it, suspended by a thread, remains slightly above the surface. Or objects of any kind, such as pieces of stick, strips of calico, or pieces of string, may be suspended above the aquarium so that they touch the bottom, or else rest on the tops of submerged objects.

When the pupa is about to change, it creeps up out of the water, and then remains quite still, save for a few slight movements of the body that give one the idea of a creature ill at ease. Then, after a short time, the skin, which is now loose on the body, gets dry and splits. Almost immediately the insect shows evidences of its desire to escape from its old coat, and it gradually frees its head and legs by contorting the body. At last the head and thorax are quite free, and it is not long before the perfect insect is entirely without its pupal skin, which is still clinging by the claws to the object on which the pupa rested. Thus the Dragon Fly leaves a coat, complete even to the skin of the legs and claws, and often so perfect that it might easily be mistaken for the former occupant.

But now let us watch the Dragon Fly itself. Its body is very soft, and its newly exposed skin moist and flexible; and the creature is, for the time, quite helpless. The wings are small, creased, and unsightly; and so soft that they bend with the slightest pressure.

A change soon takes place, however. The wings gradually expand and straighten out, but are still soft and useless for flying. But they, and also the skin, rapidly become dry in the sun; and it is not long before the creature releases its hold and takes its first flight into the air.

FIG. 217.—DRAGON FLY EMERGING FROM THE PUPA CASE

CLASSIFICATION OF DRAGON FLIES

Dragon Flies are divided into two main groups, the *Libellulina* and the *Agrionina*. The members of each group may be very readily distinguished by the form of the head, which in the former is massive, and rounded in front; but in the latter is small, and very wide from side to side. There is also a ready means of distinguishing between the two divisions in the wings, the hind pair in the case of the insects of the first group being very wide at the base, while all four wings of those of the second group are narrow at the base. Nor is there any risk of confusing these two groups in their earlier stages. We have already referred to two distinct types of the larvæ of Dragon Flies, the one distinguished by a short and broad abdomen, and a respiratory cavity formed by the enlarged rectum, surrounded by a number of fine tracheal tubes; and the other with a slender body, terminating in three leaflike respiratory plates. The former is a type of the *Libellulina*, and the latter of the *Agrionina*.

The *Libellulina* is subdivided into two groups—the *Libellulinæ*, with head about the same width as the thorax, and the ocelli arranged in the form of a triangle; and the *Æschninæ*, with head wider than the thorax, and the ocelli placed in a straight line.

These, again, are divided into families, the *Libellulinæ* into two families—*Libellulidæ* and *Corduliidæ*; and the *Æschninæ* into the *Gomphidæ*, *Cordulegastridæ*, and the *Æschnidæ*.

Similarly the section *Agrionina* is divided into two families—the *Calopterygidæ*, with broad and beautifully coloured wings; and the *Agrionidæ*, with narrow and transparent wings.

It would be uninteresting to enumerate here all the chief distinguishing characteristics of the various families, genera, and species of the whole of the British *Odonata*; but nevertheless such particulars are essential to aid those who would study the relationships of the insects, and would arrange their specimens in the cabinet in their proper order.

I shall therefore supply sufficient information to enable the reader to identify and arrange his specimens, putting the same in a tabular form, so as to be convenient for ready reference.

Before doing this, however, it will be necessary to explain a few terms that will be used, not that the actual terms are absolutely necessary to enable one to correctly describe the insects in question; but they are very convenient, since they allow us to express ourselves in a very concise manner.

First, with regard to the head of the Dragon Fly, we have already observed that the large compound eyes form the bulk of it. When, however, the colour of the *head* is spoken of, the eyes are not included, and the note is intended to apply only to the space between them. The simple eyes, or *ocelli*, are placed on the crown of the head, and the arrangement of these is in some cases important, as it assists us in distinguishing between species. It will be observed that in the case of *Platetrum depressum*—one of our commonest species (fig. 218)—the large compound eyes meet in the middle line above, occupying so much space that the crown of the head is very small. When the eyes meet in this way, they are said to be *contiguous*. Our illustration also shows the arrangement of the three ocelli, and the short antennæ arising from the inner edges of the compound eyes.

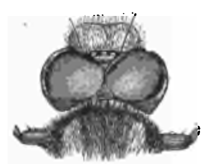


FIG. 218.—HEAD OF *Platetrum depressum*, ENLARGED; SHOWING THE LARGE COMPOUND EYES, THE OCELLI, AND ANTENNÆ

Fig. 219 shows the arrangement of the same parts in another common species—*Cordulegaster annulatus*. Here the compound eyes also meet, but are narrowed down to such an extent towards the inner side that they only just touch at a point; and the ocelli are arranged in a line. In other species of the same tribe (*Æschninæ*) the head is similar except that the compound eyes do not touch at all.

FIG 219.—HEAD OF *Cordulegaster annulatus*, ENLARGED

FIG. 220.—HEAD OF *Calopteryx virgo*, ENLARGED

Our next sketch illustrates a marked difference, for the head is very wide in proportion to its length, and the large globular eyes are very remote, being placed on the extreme sides of the head.

We will now examine the wing of a Dragon Fly, making use of an enlarged sketch that we may better delineate the delicate nervures or wing rays.

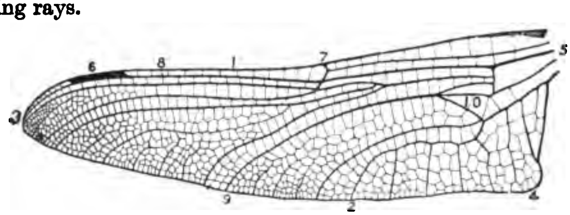


FIG. 221.—HIND WING OF *Coraulegaster annulatus*, ENLARGED

1, costal nervure; 2, hind margin; 3, tip; 4, anal angle; 5, base; 6, stigma; 7, cubital point; 8, principal radius; 9, medial radius; 10, triangle

That portion of the wing which is joined to the body is termed the base. The front margin is the *costa*, and is supported by the *costal nervure*; and the opposite edge is termed the *hind margin*. In this particular wing there is an angle at the hind margin, close to the base, and this is called the *anal angle*. Close to the base, between it and the anal angle, is a membrane called the *accessory membrane*. On the costal margin, near the apex of the wing, is an elongated black spot called the stigma. About halfway between this and the base of the wing there is a point marked by a short but strong transverse nervure: this point is known as the *cubital point.* It will be seen that there are about twelve or more short transverse veins between the cubital point and the base of the wing, each running from the costal nervure to another parallel with it, thus dividing the long and narrow intervening space into so many little square areas. An observation of the number of these little nervures is often useful when identifying and classifying the different species. Further, it will be observed that a few of the principal nervures run direct from the base of the wing to the tip and the hind margin. These are called *radial nervures*; others, branching from them, and running uninterruptedly to the hind margin, dividing the wing into large segments, are called *sectors.*

It is interesting also to note the different shapes of the very small areas of the wing enclosed by the smallest nervures. Many of these, especially near the costal margin, are four-sided; while the smaller ones towards the tip and the hind margin have five or six sides.

Near the base of the wing there is a very conspicuous triangular space, enclosed by three strong nervures, with its apex directed towards the hind margin. This area is termed the *triangle*, and in the case of *C. annulatus*—the species of which the wing is figured—it is divided into smaller areas by a delicate transverse nervure.

When describing the form and colour of the different species of Dragon Flies, it will be frequently necessary to mention the segments of the body, calling them by their numbers; and, in order to avoid mistakes in this direction, it is desirable that some attention should be given to the general build of the body of these insects.

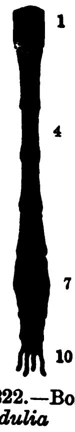


FIG. 222.—BODY OF *Cordulia ænea*, ENLARGED, SHOWING THE SEGMENTS OF THE ABDOMEN

The illustration (fig. 222) represents the abdomen of one of the *Corduliidæ* (*Cordulia ænea*), enlarged, and with some of the segments numbered. As regards the thorax, it will be remembered that it has three segments, each bearing a pair of legs; and that the wings are attached to the second and third segments. The abdomen, it will be seen, consists of ten segments, and these are generally so distinct in the Dragon Flies that it is not at all difficult to make them out. The tenth segment usually bears two pairs of appendages, the form and arrangement of which vary in the different genera.

In *C. ænea* the upper appendages are cylindrical in form, while the lower are curved like a claw and deeply notched. In *Platetrum depressum* they are very small and inconspicuous. Those of *Æschna cyanea* are long and flattened in the male, shorter and narrower in the female. In *Lestes sponsa* the upper ones are curved like a pair of pincers, and toothed on the inner side; and the lower straight and narrow.

FIG. 223.—THE ABDOMINAL APPENDAGES OF *Cordulia ænea*, ENLARGED

Having called attention to these few particulars, we will proceed with our table of the families.

Table of the Families of Dragon Flies

I. Head large, and rounded in front. Hind wings broad at the base. Larva with short and broad abdomen. (Section LIBELLULINA.)

A. Head about same width as thorax. Ocelli arranged in a triangle.

1. No metallic colours. Family LIBELLULIDÆ.
2. Abdomen club-shaped. Metallic colours. Family CORDULIIDÆ.

B. Head wider than the thorax. Ocelli in a line.

3. Eyes not contiguous. Family GOMPHIDÆ.
4. Eyes just meet at a point. Family CORDULEGASTRIDÆ.
5. Wings broader. Eyes contiguous. Family ÆSCHNIDÆ.

II. Head small and wide. Eyes very remote. Abdomen slender. Larva long and slender, with three flat abdominal appendages. (Section AGRIONINA.)

6. Wings wide and deeply coloured. Bright metallic colours. Family CALOPTERYGIDÆ.
7. Wings narrow and transparent. Only two nervures on the costa before the cubital point. Family AGRIONIDÆ.

Family LIBELLULIDÆ

This family contains thirteen British species, but only four of these are really common insects. In one case (that of *Leucorrhinia* *pectoralis*) the insect has been placed on the British list on the strength of one single specimen, which was taken near Sheerness about thirty-five years ago. Of *Sympetrum meridionale*, only a few specimens have been taken, and these near London; and of *S. Fonscolombii*, only three.

It is interesting to note that insects which are placed on British lists on the strength of one or two captures are generally taken in the extreme south, and, moreover, belong to species which are more or less abundant on the other side of the Channel. Hence we have reason to believe that they are not true natives of Britain, but consist of specimens which have strayed or have been blown over from their own country, and their appearance in our maritime counties ought rather to be regarded as accidental.

It is only fair to add, however, that such may not be the case—that the specimens taken were insects which were born and bred in our own ponds; and even the youngest of our pond-hunters should keep on the watch for such rarities, for it is possible that he may not only become the fortunate possessor of one of these gems, but that he may also gain such experience as will enable us to claim these rare insects as our own, or even add fresh species to our *Odonata*.

One of the commonest species of this family is *Platetrum depressum*, the female of which is figured on Plate IV. It is a powerful insect, with a broad, flattened abdomen. It strays far from the water, and may be seen sailing backwards and forwards in wooded places, often confining itself to one small tract.

So defiant is it when attacked with the net, that it sometimes seems advisable to strike when there is really no chance of reaching it, for it will often make a nearer approach after the first assault, as if to challenge your skill; and will sometimes, after darting by you two or three times, suddenly alight on a twig quite within the range of your net.

Chase is perfectly hopeless with the largest and most powerful insects of this family. Your only chance is to stand in wait, striking when a good opportunity occurs, and stealthily following them up when they show an inclination to settle.

Another peculiar feature of this and some of the other large Dragon Flies is their great tenacity of life. Many instances of this have been recorded, but the most remarkable case that ever came within my own experience is the following:

On one occasion I struck at a *Depressum* as it was flying past, I was successful, or at least partially so, for on examining the net I found that I had the creature, minus its abdomen. The hoop of the net had struck it, severing the body at the waist, and enclosing the fore portion only. The thorax and head were quite uninjured, and the wings were intact. After examining the half-insect for a time, and noticing with surprise how little it seemed to care for the loss of such a large portion of its anatomy, I placed it on the ground. Immediately it began to fly, but it could not balance itself well, and was easily caught again. Just then I caught a large fly that had caused me some little inconvenience by persistently settling on my perspiring face; and, without anticipating the result, held it close to the jaws of the Dragon Fly. Without a moment's hesitation the creature began to chew vigorously, and soon devoured the whole of the fly with the exception of the wings. I was previously well aware of the fact that some species of Dragon Flies will eat readily from the hand as soon as they are captured, and while still held in the captor's hand, but this was a decided advance on such indifference, for here was an insect taking food, apparently with a relish, and having no stomach in which to digest it! And this is not, I believe, an isolated case of its kind, for I have heard of others who have had similar experiences with the larger Dragon Flies.

It is doubtful, to my mind, whether the act just referred to on the part of Dragon Flies is prompted by hunger or sheer savagery; for they will chew up a straw or any other such substance presented to their powerful jaws. It should be noted, however, that they will generally swallow parts of the flies that may be presented to them, while the chips of straw &c. are allowed to fall to the ground.

Returning again to the unfortunate *Depressum* mentioned above, it should be mentioned that the fly given to it was actually eaten, and fragments of its body were seen to emerge at the back of the thorax. And, further, the Dragon Fly seemed so unconcerned at the loss of its abdomen, that there appeared to be no immediate need to kill it in order to terminate what might be supposed to be a painful existence. So I boxed it, and, on arriving home, placed it in a large vivarium. Here it remained comparatively quiet for nearly two days, after which time a brilliant sun roused it to activity. But its glee was cut short; for a green lizard, occupying the same case, attracted by its attempts to fly, soon attacked it, and seemed to enjoy the meal, except that it had considerable difficulty in disposing of the large and broad wings.

The general characteristics of *P. depressum* may be observed in the illustration on Plate IV (fig. 1), where the female is figured. The male differs in having the abdomen covered with a cobalt bloom, and yellow spots exist on the sides of the middle segments only.

This species, as well as other common insects of the same family, is often called the 'horse-stinger' by the country folk, who will declare that they have *seen* it sting horses as they feed in meadows or as they walk through the lanes. But there is not the slightest foundation for the name, nor can there be any other than purely imaginary reasons for the statements made.

Libellula quadrimaculata (fig. 224) is another well-known insect of the same family. It is not so generally distributed as

FIG. 224.—*Libellula quadrimaculata*

P. depressum, but it is often very abundant where it occurs. Those who live in the metropolitan district should search for it in Epping Forest, where it is tolerably plentiful; and the New Forest—a famous hunting-ground for entomologists—is also one of its favourite resorts.

It varies considerably in brilliancy of colouring. In fact there are two or three distinct varieties of the species. It may be distinguished from the last species by its narrower and tapering abdomen, also by the presence of a dark spot on the middle of the costa of each wing.

There are also two common species belonging to the genus *Sympetrum*, both of which are considerably smaller than the two previously named. One of them—*S. vulgatum* (fig. 225)—is most abundant in the southern counties, while the other—*S. scoticum* (fig. 226)—abounds more in the north; but both are generally distributed

FIG. 225.—*Sympetrum vulgatum*

S. vulgatum is about an inch and a half long, and two and a quarter inches in width, from tip to tip. The thorax is of an olive-brown colour, with three black stripes on each side; and the abdomen is reddish olive, marked with yellow between the segments.

S. scoticum is much smaller, being less than an inch and a quarter in length, and only two inches across. The head, thorax, and abdomen of the male are all of a blackish colour tinged with

FIG. 226.—*Sympetrum scoticum*

purple, and the eyes green. The female is olive, except the hinder half of the eighth and ninth segments, which is black. The wings, especially the hind pair, are slightly tinted with yellow.

Other species of this family may be taken by the young collector; but as it is impossible to give descriptions of all, we append a table which will enable the reader to classify his captures.

Family LIBELLULIDÆ

I. Antecubital nervures ten to sixteen in number.

A. Abdomen broad and flat. Genus PLATETRUM.

B. Abdomen thick, tapering. Genus LIBELLULA.

C. Abdomen cylindrical. Genus ORTHETRUM.

II. Antecubital nervures six to eight. Length of body an inch and a half or under.

D. Dark spot at base of wings. Genus LEUCORRHINA.

E. No spot at base of wings. Genus SYMPETRUM.

The reader should first determine the family to which his captures belong, by the help of the table on page 262. Having settled this matter, he should place each in its proper genus, making use of the small tables given under the heads of the families.

In the case of the present family the following notes may prove useful:

The genus *Platetrum* contains only one British species—*P. depressum.*

The second genus (*Libellula*) contains two; one, *L. quadrimaculata,* which may be known by the spots on the middle of the costa of each wing; and the other, *L. fulva,* a very rare species, without such spots.

In the genus *Orthetrum* there are also two species, but both very local in their distribution, especially *O. cancellatum,* which may be recognised by the brown accessory membrane. In the other (*O. cærulescens*) this membrane is white.

As regards the genus *Leucorrhina,* the young collector can hardly expect to secure a representative; for besides *L. pectoralis,* of which, as we have already pointed out, only a single specimen has been taken in Britain, there is only one species—*L. dubia,* which is exceedingly rare.

The last genus—*Sympetrum*—contains a few smaller insects, none of which exceeds an inch and a half in length. The smallest of these is *S. scoticum,* and this species and *S. vulgatum* have already been named as the only two of the genus that are generally distributed. *S. flaveolum* and *S. sanguineum* are both very local. The latter may be known by the blood-red stigma, and the former by its black nervures.

Two other species have been added to the British members of this genus on the strength of two or three recorded captures,

Family CORDULIIDÆ

We have only three species of this family, and they represent as many genera. They are all beautiful insects, being rendered so by the brilliant metallic hues of their bodies.

One only of these is likely to be seen at large by young collectors, but it is possible that one or both of the others may be taken.

The commonest species is *Cordulia ænea* (Plate V, fig. 1), the head, thorax, and abdomen of which are all of a beautiful brassy green colour. The eyes are also green, and the mouth yellowish brown. The wings are stained with yellowish brown at the very base, and those of the female are very slightly stained with brown throughout.

It will be observed that the triangle of the forewings is not equilateral, and that a strong nervure runs from the middle of the base to a point very near the apex, on the outer side. Other nervures are usually present within the triangle, but these are not by any means constant.

The abdomen of *Ænea* is also club-shaped.

This beautiful insect is moderately common in the south and south-eastern counties. I have taken several within a few miles of London.

Although the other two species of this family are rare, yet I include a little table which will serve for their identification, hoping that the reader may be so fortunate as to require its aid.

Family CORDULIIDÆ

I. Triangle of forewings not equilateral, and crossed by a transverse nervure.

A. Face with yellow spots.	Genus SOMATOCHLORA.
One species (very rare).	*S. metallica.*
B. No yellow spots on face.	Genus CORDULIA.
One species (generally distributed).	*C. ænea.*

II. Triangle of forewings equilateral, and having no transverse nervure. Genus OXYGASTRA.

C. One species (very rare).	*O. Curtisi.*

It will be interesting to note here that the last of these species is to be found in Britain alone, and, being also very rare, would be regarded as a great acquisition by any entomologist. It is to be hoped, however, that, should a collector happen to find the insect tolerably plentiful in any locality, he will not be tempted to take life unnecessarily for the purpose of merely adorning his cabinet. The total extinction of this beautiful insect would be deemed a great loss by all true lovers of insect life.

Families GOMPHIDÆ and CORDULEGASTRIDÆ

The first of these families is not likely to come within the ken of the reader, for it contains only three species, two of which have been added to our list through the capture of a single specimen. The third (*Gomphus vulgatissimus*) is very rare and very local, having been taken in but few localities in the southern and south midland counties.

This species is nearly two inches in length, and a little over two and a quarter across. The wings are entirely transparent, with stigma of a bluish colour; and there is a deep notch at the anal angle. The head is brown, and crossed by three black lines, and the eyes are of an ashy grey colour. The thorax is yellowish, with two dark lines above, and two others on each side. The abdomen is marked with black and yellow above, and spotted with yellow at the sides.

Of the *Cordulegastridæ* we have only one species, but this a moderately common Dragon Fly. It is very widely distributed, but seems to favour only certain localities. I have taken several in the wooded hills in the neighbourhood of Bournemouth, particularly on the slopes of the Branksome Chine.

It is a very rapid flier; and, like *Depressum* and other large species, it confines its ravages to one particular limited area, darting to and fro after its insect food, often skimming the surface of the water, but sometimes confining its attentions to a little track of wooded ground some distance from the nearest pond or stream.

The species to which we refer is called *Cordulegaster annulatus* (Plate IV, fig. 2), and it is, both as regards size and colour, a really fine insect.

Its body measures about two and three-quarters of an inch in length, and the width from tip to tip is quite three and a half inches; but a variety of the species that is considerably smaller is occasionally met with. The head is yellow; the thorax black, with three golden yellow stripes on each side, and two, placed obliquely, above The abdomen is club-shaped—a feature which has given rise to the generic name, for the word 'cordulegaster' signifies 'club-bellied.' The general colour of this portion of the body is black or dark brown, but most of the segments are variously marked with a bright golden yellow. The first segment is yellow at the sides; the second, before and behind; the third, fourth, fifth, sixth, and seventh, across the middle; the others are entirely dark with the exception of small dots on the last but one. The wings are transparent in all parts with the exception of the usual stigma.

Family ÆSCHNIDÆ

This family includes eight British species, all of which are large insects; but only two of these can be described as common, and it is feared that one of them—*Æschna rufescens*—is very nearly extinct.

The typical genus contains two fine insects that must have exhibited their masterly flight to all frequenters of the country.

One of these—*Æschna grandis*—is often to be seen during July in all kinds of localities, for it frequently strays far from the water which formed its home during the earlier stages of its existence, and even ventures into gardens in the midst of our towns. It seems very partial to woods, and will often fly high among the topmost branches of tall trees, and settle there at times to devour its prey.

The body of this insect is two and three-quarters of an inch long, and the wings measure nearly four inches across. The head and thorax are red, the latter with two yellowish patches on each side. The abdomen is also red, spotted with blue in the male and with yellow in the female. The wings are stained with brown, and the nervures are of an orange colour.

The other species referred to is *Æ. cyanea*, and this one is still more common. Like the preceding insect, it frequents all manner of localities, and it is also similar in its habits. Such powerful fliers as these are not easily taken in the net, and they often make a dart over the tops of tall trees when attacked. A very bright day with passing clouds is the best for the hunter of these creatures. As long as the sun shines brightly they keep actively on the wing, and a sharp eye is required to follow their movements. But as soon as the shadow of a dense cloud covers their beat, they settle on a twig to rest. If, now, the observer has been fortunate enough to see where one of them alighted, he should have little difficulty in securing it with a sharp sweep of the net.

Æ. cyanea may be distinguished from *Æ. grandis* by the bright greenish blue eyes, and the two large oval greenish spots on the front of the thorax. The abdomen of the male also is spotted with greenish blue, but the spots of the female are yellow. The wings are stained with yellow, and the stigmata, which are shorter than in *Æ. grandis*, are black in the male and brown in the female.

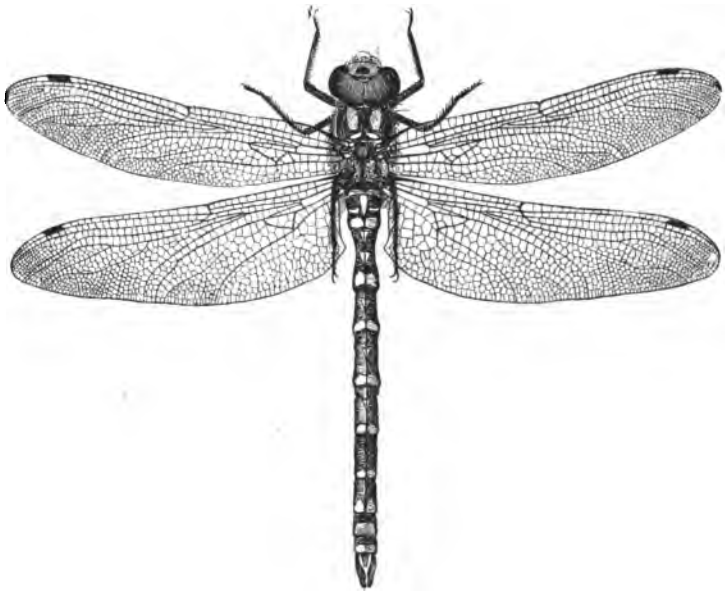


FIG. 227.—*Æschna cyanea*

Æ. juncea, unlike most of the Dragon Flies, is more abundant in the North than in the South; and is found to be far more plentiful in Scotland and Ireland than in England. It is not so abundant as the two members of the same genus just mentioned, but is plentiful in some northern localities.

The thorax of this species is brown, with two very broad yellow oblique stripes at the sides, and two narrow ones in front, the latter being broken in the female. The abdomen is spotted with blue in the male and with pale yellow in the female. The wings are stained with brown, and the stigmata are long and narrow.

There are two other species in this genus. One of them, *Æ. borealis*, has been taken only in Perthshire; and the other, *Æ. mixta*, though widely distributed, is regarded as a rarity.

The former has blue lateral and front stripes on the thorax, and the abdomen is spotted with blue in the male and with yellow in the female. The latter has the thorax spotted and striped with a yellowish colour. The abdomen is brown, with black bands, and is marked with yellow in the male and with green in the female.

The remaining species of the family are *Brachytron pratense*—a very local insect, the whole body of which is hairy; and *Anax formosus*, which is the largest of all the British Dragon Flies, also very local, but widely distributed.

Family CALOPTERYGIDÆ

No one could possibly mistake the members of this exceptional family. It contains only two species, and both these have very broad and coloured wings. These wings, however, are not wide at the base, like those of the *Libellulinæ*, and there is no anal angle. The neuration of the wings is exceedingly delicate, and the bodies are adorned with brilliant metallic hues.

The country folk often show their appreciation of the beauty of these brightly coloured insects by naming them 'Kingfishers,' and the French honour them with the title 'Demoiselles.'

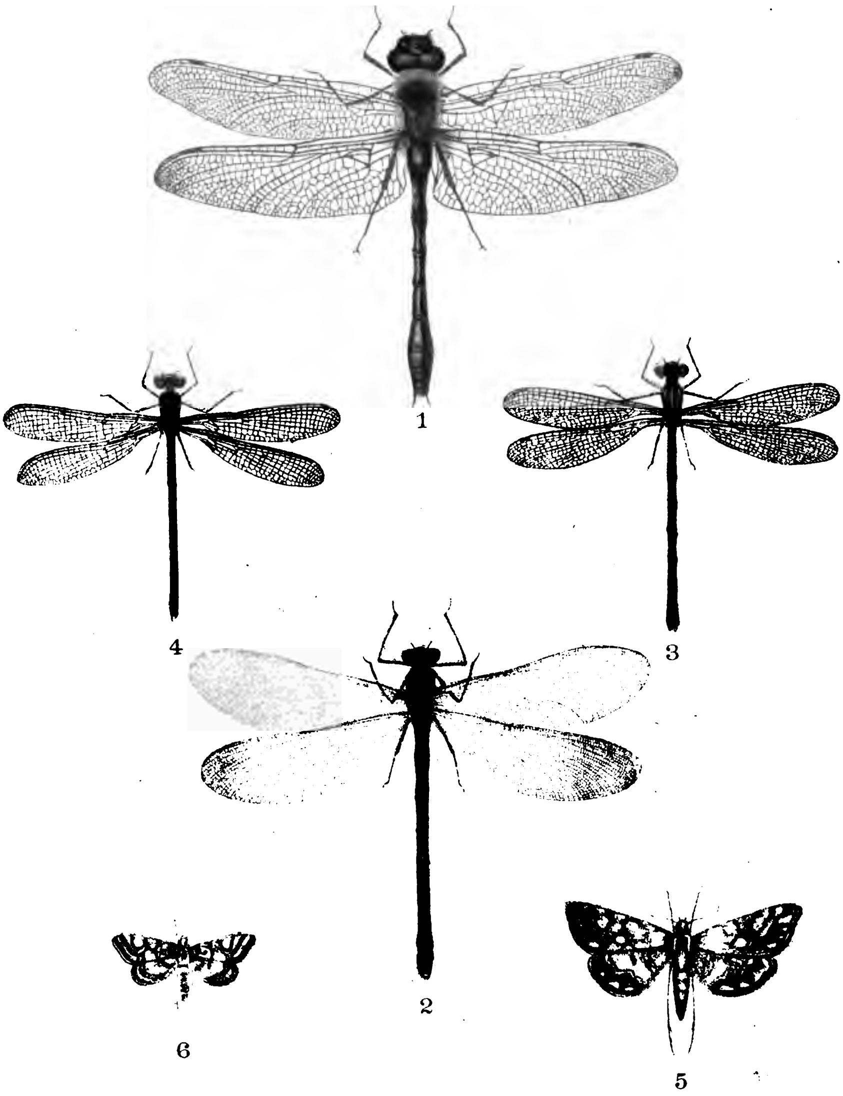
There is a very great difference in the general habits and flight of the *Calopterygidæ* and those of the various Dragon Flies previously mentioned. Most of the latter remind us of the powerful and rapacious birds of prey, while the former are more fitting emblems of the small, brightly coloured and social song-birds.

They are seldom seen singly, but dance about in the air in little groups, something after the manner of gnats, and generally remain immediately over the water of a stream or pond, apparently far more attentive to their frolicking games than to the numerous insect delicacies that swarm in the immediate neighbourhood.

Their flight is so weak, and their habit of remaining in one restricted spot is so persistent, that there is no difficulty in catching them, provided they are within reach of the net; but they frequently tantalise the collector by hovering over the middle of a stream that is just wide enough to prevent them being within range from either bank.

I have often found it necessary to cut a stick, several feet in length, to tie to the stick of the net in order to make it sufficiently

PLATE V.



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... *virgo* (Plate V, fig. 2) are of a brassy ... is also generally of the same ... very red. The wings of the male ... base and the apex, where they are ... there are no stigmata. Those of the ... have a white stigma some distance from

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... head and body are of ... and with even finer ... are yellowish and glassy, with a ... black. Those of the female are pale ... is nearer the tip than in *C. virgo*.

AGRIONIDÆ

... largest family of our Dragon Flies, but ... of them exceeding an inch and a half ... quarters across. In all of them the ... nt, and the stigma is rhomboidal in ... sloping backwards and inwards. ... have been entered on the British list, ... a claim to be placed there only on the

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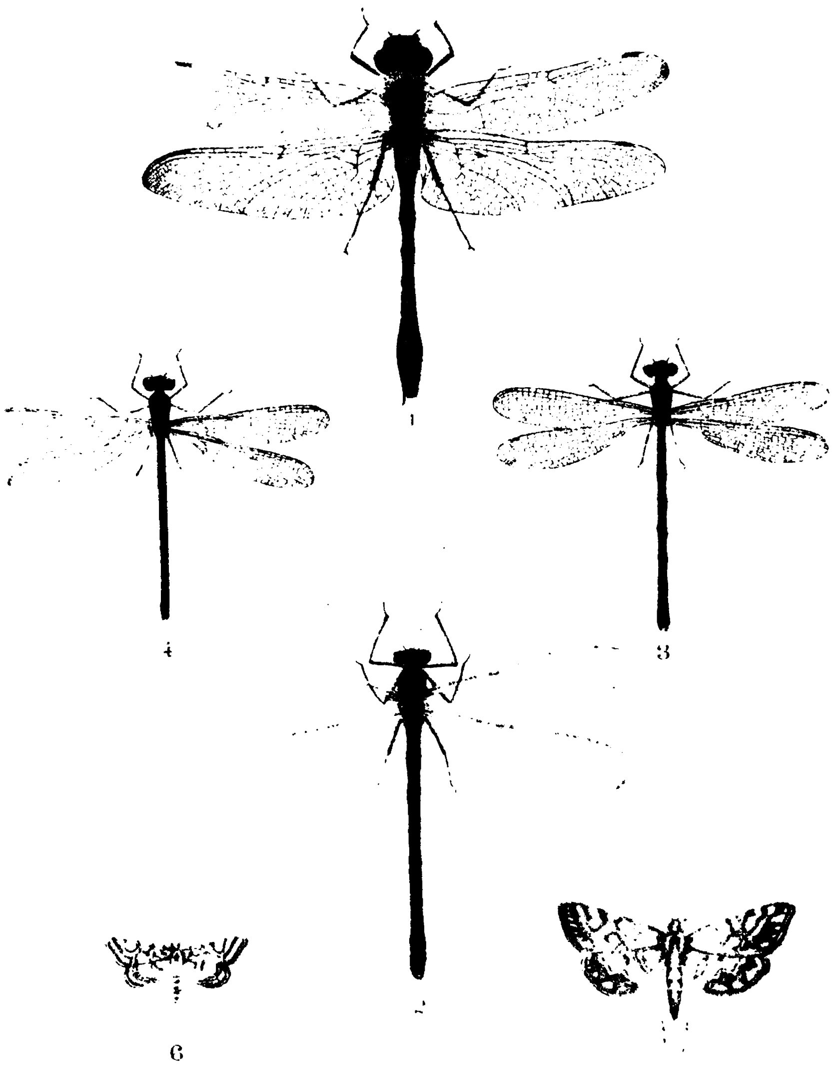
PLATE V.



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long for this purpose; but the instrument, though more or less successful after being thus lengthened, is very awkward, and of course cannot be swept so rapidly through the air. Another difficulty is sometimes experienced by the selection, on the part of these insects, of a nook protected by tall and overhanging vegetation that greatly interferes with the vision of the naturalist as well as with the movements of the net.

There are two British species of this family—*Calopteryx virgo* and *C. splendens*. They are both of the same dimensions, the body being about an inch and three-quarters long, and the breadth from tip to tip two inches or more.

The head and thorax of *C. virgo* (Plate V, fig. 2) are of a brassy green or blue colour. The abdomen is also generally of the same hue, but sometimes of a rich coppery red. The wings of the male are bluish black except at the base and the apex, where they are transparent and yellowish, and there are no stigmata. Those of the female are brownish, and have a white stigma some distance from the tip.

It should be noted, however, that this species is subject to much variation. Sometimes the wings of the male are brown or smoky, and those of the female are occasionally tinged with green.

This is one of the earliest of our Dragon Flies. It sometimes appears early in May, but June and July are good months in which to search for it; and I have taken several specimens in the New Forest as late as the last week in August.

C. splendens is a very similar insect. The head and body are of the same colour, but the wings are narrower, and with even finer reticulations. Those of the male are yellowish and glassy, with a broad central patch of bluish black. Those of the female are pale green, and the white stigma is nearer the tip than in *C. virgo*.

Family AGRIONIDÆ

This is the last and the largest family of our Dragon Flies, but all the species are small, none of them exceeding an inch and a half in length and one and three-quarters across. In all of them the wings are narrow and transparent, and the stigma is rhomboidal in form, the outer and inner edges sloping backwards and inwards.

Of the fifteen species that have been entered on the British list, there are three that have a claim to be placed there only on the strength of one or two captures. Five may be described as common, and all the others are more or less local and rare.

Their flight is short and weak, hence they are easily captured with a net when on the wing; but being so very slender and fragile, it requires an experienced eye to follow their movements in bright sunshine. The exceedingly slender bodies, almost invisible at even a short distance, and the colourless wings are rendered apparent only by their reflection of the sun's rays.

These Dragon Flies seldom stray far from the water in which they spent their earlier days, but usually flit about among the flags and other semi-aquatic plants round ponds and on the banks of sluggish streams. In the case of damp meadows and marshy ground they are less restricted, and may be found settling on rank herbage in all directions, and sometimes seek the shelter of the neighbouring hedgerows.

In dull weather they are very sluggish, scarcely moving at all, but remaining at rest on the herbage with all four wings folded together over the back. At such times they may be lifted from their resting places by the wings and boxed at pleasure.

The commonest species of the largest genus (*Lestes*) is *L. sponsa* (Plate V, fig. 3); and so plentiful is this one in certain localities that almost every flag and rush supports one or more, and as they flit about in the sunshine a dozen or so may be taken in the net at one sweep.

The head, thorax, and abdomen are all of a metallic green colour, except that the last two segments of the male are blue. The upper abdominal appendages are curved like a pair of pincers, and the lower ones are straight. The stigmata of the wings are black.

Another species of the same genus—*L. nympha*—is widely distributed, but very local. Its body is of the same colour as that of *L. sponsa*, but the male is powdered with blue, and the stigma of the wing is smaller than in the last species.

The typical genus (*Agrion*) contains three interesting species. Of these *A. puella* (Plate V, fig. 4) is very common and generally distributed, and, like *L. sponsa*, literally swarms in some neighbourhoods. The male is blue and marked with bronze colour, but in the female the ground colour is bronze and the spots blue.

This insect appears on the wing in May, and continues to fly till about the end of July.

Agrion pulchellum is also widely distributed. It is more local than the last species, but is very abundant in many places. Its body is bronze-coloured, spotted with blue. The female has two little spots on the hindmost part of each segment of the abdomen.

The other insect of this genus is *A. mercuriale*, which is the smallest of all the British *Odonata*.

Enallagma cyathigerum (Plate IV, fig. 3) is another of our common *Agrionidæ*, and the only one of its genus. Its body is bronze, spotted with blue, and the stigma of the wing is rhomboidal in form, and short. This species is common in the North.

Two others must be mentioned, and these are the common *Pyrrhosoma minium* (Plate IV, fig. 4), readily known by the bright red body; and *Ischnura elegans*, the abdomen of which is black with the exception of the eighth segment, which is blue. In both these species the stigma is small and rhomboidal. The former is a very common insect; the second also is common, but more local.

May Flies (*Ephemeridæ*)

On a summer's evening, late in May or in the beginning of June, we may see swarms of flies, with delicate gauzy wings that measure an inch or more across, dancing up and down in the air over the edge of a stream or large pond, and often touching the surface of the water with very long filamentous appendages that arise from the tip of the abdomen.

Their merry movements continue in the dusk till we can no longer distinguish their fragile forms; but still we are aware of their presence; for, as we walk along the path by the water's edge, we now and again come into contact with a group of them, and feel the rustling of their fragile wings and the sweeping of their slender filaments on our faces.

If we happen to be on a nocturnal entomological hunt, and possess the lantern so essential on such occasions, we throw our light towards the water, and then they approach from the darkness, attracted by the gleam, and even play against the glass.

On the following morning we visit the spot again, but the swarms have disappeared. However, on examining the flags and other herbage, we may succeed in finding a few at rest. So sluggish are they now that they are easily taken by the wing between the finger and thumb. A few fly as we approach them, but only to settle again immediately on some neighbouring plant.

Later in the day, when the sun is high, we walk over the same ground again, but all have disappeared.

In the evening we witness the same sight again, and perhaps for an evening or two after; but their numbers rapidly diminish, and no more are to be seen till the corresponding season of the following year.

These insects are known as May Flies (*Ephemeridæ*), and their sudden appearance in countless swarms, their equally sudden disappearance, and the remarkable peculiarities of their metamorphoses, have made them objects of attraction to naturalists from very early times.

The perfect insects are very fragile creatures. They have two pairs of wings, the front ones being long and broad, but the hind pair very small, and in some species quite rudimentary.

The antennæ are short and inconspicuous, but the front pair of legs, which are very long and slender, are thrown forward when the insect flies, so that they look just like a pair of long antennæ.

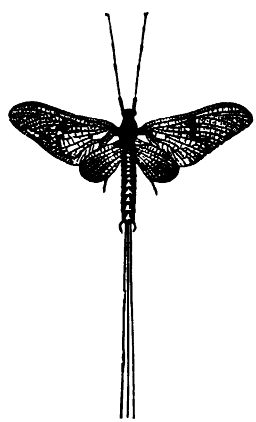

Fig. 228.—May Fly (*Ephemera vulgata*)

At the tip of the abdomen there are two or three very long hairy appendages, generally much longer than the body of the insect, and so fine that they are hardly visible as it flies.

When we look closely into the structure of the wings we are reminded at once of those of the Dragon Fly, for they consist of a delicate transparent membrane, supported by a fine network of nervures. The chief nervures extend from the base of the wing to the tip and hind margin, running almost parallel with one another; and the lesser ones join these at right angles, thus dividing the membrane up into a number of little four-sided cells, which are smallest at the tip and along the hind margin, and comparatively large at the base and in the middle of the wing.

Like other insects, the May Fly is provided with a pair of compound eyes; but the organs of the mouth, which, we have seen, are so well developed in Dragon Flies, and which, even in the Bugs, form a complicated suctorial organ, are here in such a rudimentary form that the insect is practically mouthless. It has not the slightest power of taking food of any kind; and, after all, this is not surprising when we consider the very brief duration of the winged state. As a larva, it fed, and fed well; and during the many long months spent in the mud as a grub it stored up just sufficient energy to enable it to perpetuate its species, for which purpose alone it assumes the winged state.

The eggs are laid on the surface of the water, the whole batch from one female being deposited at the same time. They are slightly heavier than their own volume of water, and therefore sink immediately, but slowly. Again, they are not glued together like those of so many other insects that lay their eggs in a cluster, hence they become scattered as they descend; and the dispersal is aided by the peculiar form of the eggs, which are little flattened discs. Were they of a globular form, they would of course sink perpendicularly unless drifted by the force of a current, and even then all would keep fairly well together, being impelled by the same force. But as a result of the greater resistance offered by their flattened faces, they spread out in all directions.

The young larvæ, as soon as they escape from the egg, burrow into the mud at the bottom of the stream, just as though they were quite aware of their defenceless condition, and of the numerous enemies always ready to pounce on such delicate morsels as they are.

They seem to thrive best in sluggish rivers with muddy beds, and this may perhaps account for the difficulty one experiences in keeping them alive for any great length of time in captivity. They are not confined to rivers, however, but often inhabit the bed of large ponds, and especially those, such as millponds, in which the water, though apparently still, is continually being renewed.

As to keeping them alive in confinement, it seems that those obtained from ponds are better adapted to this treatment than those taken from the bed of streams; at least, this is my own experience. It does not appear to be possible to rear May Flies from their younger stages, and the larvæ which I have dredged from streams have never lived long even in a large aquarium. Those which I have kept longest were taken from a millpond, with a large quantity of mud, and the whole placed in a large wooden tub, in which the water was kept in almost imperceptible motion by a very fine stream issuing from a pipe.

A large quantity of mud is an absolute necessity to the larvæ of

May Flies, for they live entirely on the organic matter (chiefly vegetable) mingled with it. Like the common earthworm, they swallow mud and all, and the nutritious materials are dissolved out by the action of the digestive juices.

We will now notice the more interesting points in the structure of the larva. Its body is very soft, and made up of fourteen distinct segments. The first forms the head, the next three the thorax, and the other ten the abdomen.

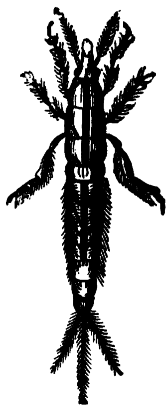

FIG. 229.—LARVA OF *Ephemera*, ENLARGED

The head is provided with two long and slender antennæ, composed of many joints, and rather thickly set with short hairs. It has also a pair of long curved mandibles.

The next three segments each bear a pair of legs, which are strong, flattened, and fringed with short hair. The foremost legs are undoubtedly the chief instruments employed by the larva when burrowing into the mud; and are well adapted for the purpose, being rounder and stronger than the others.

The appendages of the abdomen consist of several pairs of leaflike plates, attached to the sides of some of the segments; and also three long filamentous organs, jointed, and fringed with short hairs, projecting backwards from the last segment. The former constitute the breathing apparatus of the creature, and each one contains a tracheal tube with a number of fine branches on each side. It is clear, from what has already been said, that the larva must obtain its air supply from the water, for its home is its burrow, and this it seldom leaves; in fact the larva is so attractive to the carnivorous inhabitants of the water, that it would be exceedingly dangerous for it to venture out of its hole even for a moment.

Therefore the creature has no functional spiracles, as air-breathing insects have, but obtains all the oxygen required for respiratory purposes from the water, through the thin walls of the tracheal tubes of the abdominal appendages.

The larva always burrows into the mud with its head foremost, and the excavation is too narrow to enable the creature to turn. At the same time, it prefers to rest at the mouth of its tube with the head just exposed. How is this to be managed? In this way. The larva burrows for a short distance downwards, and then works itself round till its tube forms half a circle and its head is directed upwards. Continuing in this direction, it soon reaches the surface of the mud again, and settles down with its antennæ just exposed, and ready to devour any nutritious matter that may be drifted towards it. At the same time, a current of water is maintained in the burrow, for purposes of respiration, by the motion of the breathing filaments, and also by an undulatory movement of the abdominal segments.

The larvæ of a few species do not seem to burrow at all, but rest more or less concealed among weeds and other submerged objects. To these a permanent home is not so necessary, for, being covered with a horny integument, they are not so liable to fall a prey to other creatures; but the soft-bodied species, on the other hand, are so attractive to fishes that they are valued by anglers as bait.

Those in search of the latter should scrape up the bottom mud near the banks of streams, and turn out the contents of the dredge on a patch of bare ground. At first no signs of life may be seen; but if the mud be spread out till it forms a thin layer, the larvæ may be seen sluggishly wriggling out of the mire. They are helpless creatures at such times, and, like many other burrowing animals, are ill at ease except when in their holes. If placed in a glass of water they swim by an undulatory motion of the abdomen, often assisting their progress by movements of the legs; but supply them with a bed of mud, and it will not be long before they have quite disappeared beneath it.

FIG. 230.—PUPA OF *Ephemera*, ENLARGED

The growth of the larva is very slow, and, in some species at least, two years are spent in this and the pupal stages. It is possible, too, that this period is extended to three years in some cases, but it is doubtful whether the statements that have been made to this effect have been sufficiently confirmed.

The pupa is much like the larva, except that the rudimentary wings are distinctly visible in the former; and the development of the insect is so gradual that there is no definite metamorphosis by which we may distinguish between the larval and pupal forms.

The number of moults is large, and each one reveals the insect in a stage of development a little in advance of that immediately preceding it; but towards the end of the creature's aquatic life the organs of the perfect insect develop much more rapidly.

When the pupa is ready to prepare for the short aërial existence awaiting it, it creeps up out of the water, and rests on a stem for the first symptoms of the coming change. The thin skin soon becomes dry and splits, and before long the insect emerges from its torn coat.

It is apparently a perfect insect, of a greenish colour, with large wings, and threadlike filaments behind. The gill plates are completely cast off with the old skin, and the antennæ are shorter than before.

The insect soon begins to flutter, apparently with the object of testing its powers of flight, and then takes its first aërial trip to a tree or some other neighbouring object.

Here it rests again, for another change has yet to come. The new skin dries and bursts, just as the last one did only a short time previously. Again the insect emerges from a rent coat, leaving it attached by the claws to the surface on which it first alighted, looking just like a real insect.

The change in appearance is not quite so great as the last, but yet considerable. The antennæ are still shorter now, the tail filaments longer, and the wings more delicate. Its colour also is lighter, and it has lost the greenish tint it had after the last moult.

After a few more preliminary flutterings, it starts off to join its fellows in the dance over the water which we have previously described.

Thus we see that the May Fly passes through one stage more than those insects whose metamorphoses are described as complete.

The first winged insect is often spoken of as the 'false imago' (*pseudimago*), and is known to anglers as the 'Green Drake.' The true imago, which appears a little later, is called the 'Grey Drake,' and both this and the false imago are used as bait.

The final transformations of May Flies usually take place in the evening, not long before sunset, and the merry dance over the water lasts but a few hours. During this brief period the insects seek their mates, and the eggs are fertilised and deposited. This exhausts all their energies, there being no means of taking and digesting food to sustain their powers.

Some of them do not appear to emerge till after sunset, and before daylight the next morning nearly the whole of them will have perished. Thus, after spending one or two years in what we may call the preparatory stages of their existence, their short life of maturity is passed without a chance of one glance at the sun.

Another remarkable feature concerning these insects is the extreme regularity with which they make their appearance each year. For a few nights in succession they appear in thousands in their favourite haunts, and then, as if with one accord, they disappear as suddenly as they came.

It is this peculiarity, together with the extremely short duration of the winged state, and the remarkable features of the final metamorphoses, that have claimed the attention of naturalists for centuries. And the term *Ephemera*, which signifies 'for a day,' denotes one of the leading characteristics of these strange insects. The same idea is also conveyed by the popular title of 'Day Flies,' which is sometimes applied to the group.

Should the reader require specimens of the perfect insects for examination or preservation, he will find it necessary to keep a sharp watch for them at the proper season. If he resides at a spot rather distant from their haunts, an addressed post-card, left in the hands of a person whose daily calling takes him where they occur, will apprise him at the right time, and call him to witness a sight which no entomologist can afford to lose.

There are several species of these flies, and it will be an interesting work for the young naturalist to endeavour to distinguish between them; but he must remember that the bodies of the insects often shrivel up as they dry, till the chief features which aid in the identification are obliterated. Hence he should preserve a portion of his specimens in spirit or some other liquid preservative in order to maintain the natural form of the body. But even this is not altogether satisfactory, for all such preservatives will sooner or later deprive the insects of more or less of their natural colour; and those who would wish to make a study of the differences between the species should carefully examine the insects while alive, and take full notes of all the features observed, illustrating them by their own sketches if they have the ability to do so.

Stone Flies (*Perlidæ*)

Our last example of the *Neuroptera* is the Stone Fly (*Perla*), so called from its habit of resting on stones on the banks of streams.

If you wish to see this insect you must search along the banks of a rapid stream with a stony bed, in a wooded valley of some hilly district, about midsummer. Examine the surfaces of stones and rocks, either quite bare or clothed with a covering of moss or lichen; also the trunks of trees and the surfaces of other objects close to the stream.

It is a very sluggish fly, of a brownish or yellowish colour, and its large wings are folded over its body as it sits, the latter being completely hidden by them.

The body is broad and flattened, and rather clumsily built. The head is wide, with the two compound eyes at the sides, and two long and slender jointed antennæ immediately in front of them. The organs of the mouth are not well developed, and the insect takes no food in its winged state, which lasts only a few days.

FIG. 231.—STONE FLY (*Perla marginata*)

The thorax is very distinctly segmented, and the segments are so large that, together with the head, they form quite half and sometimes more than half the total length of the body. As a result of this peculiarity the wings are rather widely separated at their bases, and the second pair are situated about halfway between the head and the tip of the abdomen.

The abdomen, which consists of ten distinct segments, is of nearly the same width throughout, terminating very abruptly behind, where it is furnished with two long jointed appendages that are widely separated at their bases.

The wings, like those of the other *Neuroptera*, are formed of a thin transparent membrane that is supported by a network of nervures. The nervures are strong and conspicuous, and present none of that fineness and delicacy which characterise the wings of Dragon Flies. In fact the neuration is coarse, the areas between the nervures being large in proportion to the size of the wings, with the exception of those which lie along the costal margin.

The hind wings are nearly as long as the others, and are very much broader. When the insect is at rest they are folded longitudinally beneath the front pair.

The tarsi have only three joints, the last and longest of which is provided with a pair of short curved claws.

So sluggish are these flies that they do not fly much unless disturbed, and never seem to stray far from the spot where the pupa left the water to cast its last coat. They are often easily taken from their resting place between the finger and thumb; and when they take to the wing their flight is so sluggish and their course so straight that one can easily overtake them on clear ground and catch them in the hand.

There are several British species of the *Perlidæ*, and some of them are used largely as bait by anglers, to whom they are known by various popular names. One—*Nemoura variegata*—is often called the Willow Fly from its habit of settling on the trunks of willow trees, and this species frequents sluggish muddy streams, and even still water. *Chloroperla viridis*—another of the angler's favourites—is commonly known as Yellow Sally.

A remarkable feature of the *Perlidæ* is the great difference in the size of the sexes, the male being often much less than half the size of its mate—a fact which must be borne in mind by the beginner who attempts to distinguish between the different species.

The females lay several hundreds of small black eggs, all held together in one rounded mass by a membrane, and carries them about at the tip of her abdomen for some time before depositing them. She then drops them on the surface of the water.

The young larvæ hide themselves under stones and other objects at the bottom, and here they spend the whole of their aquatic life, apparently shunning the light, and always holding themselves in readiness to seize any creature that comes within their reach, for they are predaceous creatures.

They are not by any means active, and would undoubtedly fare badly were they dependent on the captures of open chase. They resort more to stratagem and cunning, lying in wait at the entrance of their shelter and suddenly seizing any unwary victim that comes within range. They attack larvæ of all kinds, except the very large predaceous species, and are well armed for this purpose with a pair of strong toothed mandibles.

They are much like the perfect insects in form, except of course in the possession of wings. The three segments next to the head are so large that they form about half the length of the body, and the tip of the abdomen is provided with two long and jointed appendages like those of the perfect form.

These larvæ may be taken in the autumn, and again in the spring; also during the milder days of the winter. In very cold weather they get into more secluded quarters, where they are not so easily found, and at this time they take no food.

They are not found among the contents of the pond net so frequently as the aquatic larvæ previously described, on account of their habit of hiding under stones and other objects; but they should be searched for by turning over the stones in clear running streams, for, when suddenly exposed by the removal of their shelter, they are easily taken in a small short-handled net before they have an opportunity of seeking out a new home.

If one of the larvæ be placed in a glass of water and closely examined, little tufts of hairlike filaments will be seen at the bases of the legs, and also at the bases of the abdominal appendages. These constitute the breathing organs, and all are supplied with fine branches of the tracheal system.

Being placed principally at the bases of the limbs, it will be understood that every motion of the limbs must encourage a circulation of water round them, and thus assist in aërating the creature's blood. Also, when the insect is at rest, its body is seldom motionless for a long time together; but it makes a slight movement every now and again, as if uneasy; and there is little doubt that these motions are for the purpose of causing the water to circulate round the breathing organs.

The pupa is similar to the larva, but exhibits the rudiments of the future wings. It creeps up out of the water about midsummer, and takes up a position on a stone or trunk of a tree. Here it fixes itself by its claws, awaiting the drying of its loosened skin.

The integument shortly splits down the back of the thorax, and almost immediately the imago emerges, first releasing its head and antennæ from their respective cases, then the legs, and finally the abdomen, leaving the empty skin still attached by the cases of the claws.

In some places Stone Flies are so numerous that these empty skins may be seen in abundance on objects close to the water's edge; and the manner in which they are distributed seems to show that the insects have their own favourite little nooks in the stream. In walking along the banks of some of our small south-western rivers, I have often seen, here and there, clusters of the skins on moss-covered boulders, and between these clusters hardly one was to be found.

ALDER FLIES (*Sialidæ*)

Every observer of insect life must have met with these sluggish flies. They are extremely abundant almost everywhere in the neighbourhood of fresh water, and when at rest (and it is seldom that they are not) they post themselves in very conspicuous and exposed places.

They are out in early summer, at which time they may be seen on tree trunks, rushes, palings, and in fact on almost every kind of object within a few yards of ponds or sluggish and muddy streams.

As they sit, the body is almost completely hidden by the wings, which close over it, sloping on each side like the roof of a house. When disturbed, they often start running, but sometimes take to the wing. Their flight, however, is short and heavy, and they generally settle within a yard or two from their starting place, and even at times seem to allow themselves to fall in order to avoid the trouble of flying.

FIG. 232.—AN ALDER FLY AT REST

If they are on rushes or other vegetation they can be easily swept off with a net; but when they choose walls, fences, stones, and tree trunks, they are best removed by means of a glass-bottomed pill box.

They are altogether very dingy insects, but yet not without interest. The head is large and clumsy, and the body is entirely black. The antennæ also are black, and of about the same length as the body.

Like the rest of the *Neuroptera*, the Alder Fly has four wings, each consisting of a transparent membrane, supported by a network of nervures. All four are large compared with the size of the body, but the front pair are larger than the others. The former, too, are of a smoky brown colour, and are rather awkwardly bent on the costal margin. The hind wings are of a paler colour.

A remarkable feature of these insects is the coarseness of the neuration of the wings. All the nervures are of a deep brown colour, and are very thick for an insect of its size.

We have only two species of Alder Flies, and these are very similar in size and appearance.

The larva of the Alder Fly lives in the mud of ponds and sluggish streams. It does not construct a home like the Caddis larva, but protects itself from its enemies by hiding in the mire, in which it also lies in wait for its own prey, for it is a carnivorous creature, with sufficient boldness to attack other larvæ as large as itself.

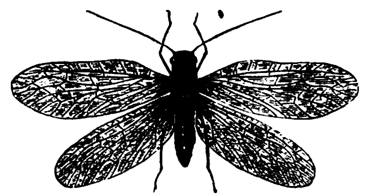

FIG. 233.—THE ALDER FLY WITH WINGS EXTENDED, TWICE NATURAL SIZE

When full grown it is nearly an inch in length; and its abdomen, which tapers off towards the end, terminates in a long pointed segment. It has two rather short but conspicuous antennæ, and its jaws are long, curved, and sharp.

It moves about by means of its three pairs of strong legs, and its progress is sometimes assisted by waving the abdomen from side to side.

The breathing organs consist of slender tapering fringed appendages attached to the first seven segments of the abdomen. These contain branches of the tracheal system, into which oxygen is absorbed from the water.

When the larva is full grown it creeps up out of the water; and when it has found a suitable spot it burrows into the soil, and there hollows out an oval cell in which to undergo its changes.

It shortly casts its skin, thus exposing itself as a pupa. At this stage its wings are distinctly visible. They are in fact quite free, as are also the legs, except that both are enclosed in the thin skin that is to be shed at the next moult.

When the perfect insect emerges it creeps up the surface of some neighbouring object to dry its wings; and it never flies far from the water in which it spent its earlier days.

The female does not go to the water to lay her eggs, but deposits them on any object within a few yards of the water's edge, so that the young larvæ have to do the best they can to find their future home.

The eggs are laid in clusters, sometimes of several hundreds. They are cylindrical in shape, slightly pointed at the upper end, and are neatly arranged side by side.

The young larvæ do not seem to be able to see the water, nor do they seem to know their whereabouts by means of any other of the senses. They instinctively walk downwards when they leave the egg case, and always seem to follow the slope of a bank; but I have observed that, if placed on the top of a ridge near the water, a large proportion of them will walk down the wrong side, and then go straight away from the bank.

It is possible therefore that a large number of these larvæ may perish through the apparent carelessness of the parent in depositing the eggs far from the water's edge, and their own inability to find their way.

Order *Trichoptera* (Caddis Flies)

This is a very small order of insects, including those popularly known as Caddis Flies, the larvæ and pupæ of which live in water.

There is a great difference of opinion among naturalists as to the true position of these insects. By some they are included with the *Neuroptera*, but usually they are placed in a separate order by themselves, and called by the name *Trichoptera*, which signifies 'hairy winged' (Gr. *trichos*, hair; and *pteron*, a wing).

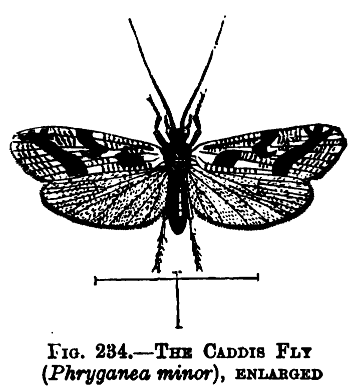

Fig. 234.—The Caddis Fly (*Phryganea minor*), enlarged

This name at once points to one of the main distinguishing features of the group, for the wings are clothed with small hairs. Some of the hairs are coloured, thus producing a distinct pattern on the wings, just as the scales do on the wings of the *Lepidoptera*. In fact some of the Caddis Flies look so much like certain moths, that they are often mistaken for them by yourg entomologists.

Caddis Flies have four wings—membranous, and supported by a network of nervures like those of the *Neuroptera*; but the hind wings are not so long as the front pair, though often much wider. When the insects are at rest the front wings completely cover the others, and the latter are folded beneath the former something after the manner of a closed fan.

The antennæ are very long and composed of many joints.

As with the May Flies, the organs of the mouth of the perfect insect are undeveloped. There are no mandibles adapted for chewing, and no food of any kind is taken by the adults.

When we examine the contents of the pond net during early summer, we frequently find a large number of cases, of a cylindrical or elongated conical form, constructed of various materials selected from the vegetation or bed of the pond.

At first they exhibit no evidence of the presence of any living inmate; but if we allow them to remain perfectly undisturbed for a short time, a head peeps out, followed almost immediately by three segments bearing three pairs of legs, giving us at once the idea of an insect form.

The creatures soon begin to move about actively, pulling their homes along as they go, but never exposing more of their anatomy than is necessary to allow the free movement of the limbs.

If we touch one of the insects, or pick it up by holding the case between the finger and thumb, the protruding segments are immediately retracted within the tube, which now appears quite as devoid of life as when first we saw it.

The insects referred to are the larvæ of Caddis Flies; and we gather a number of them, selecting as many different kinds of cases as we can, and place them in boxes with scraps of pondweeds that we may be able to observe them in confinement.

They require plenty of room in confinement, especially the larger ones; and they should have a liberal supply of soil and vegetation, for they are mostly vegetable feeders, either devouring fresh green plants, or the decaying vegetable matter that is constantly accumulating on the bed.

They climb well on the submerged vegetation; and, considering the size of some of the cases, and the heavy materials, such as stones and shells, of which they are wholly or partly composed, they seem to get along remarkably well. We must remember, however, that objects weigh less in water than they do out of it—that objects, when submerged, lose a weight equal to that of their own volume of water, and therefore the work performed by a Caddis larva is not so great as it appears to be.

Let us now examine the different kinds of cases made by these larvæ. Here is one, small, conical, and slightly curved (fig. 235, *b*), very regular in form, though not perfectly smooth, and reminding us of the marine shell known as the 'elephant's tusk.' On examination with a lens, we find that it is composed entirely of little grains of sand, cemented together with great regularity, and note with surprise that the larva selected grains of a size, just as if it were much concerned about the regular and finished appearance

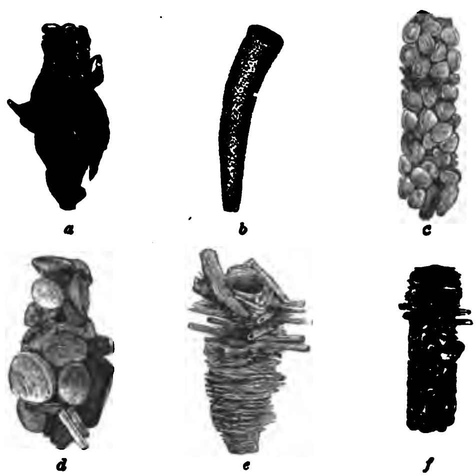

FIG. 235.—CADDIS CASES

of its domicile. The case is open at both ends, as are all the others; but the larger end only will admit of the protrusion of the inmate's head and limbs.

It will be interesting now to examine the case internally; but in order to do this we must first remove the larva. It may be supposed that this is easily accomplished by waiting till the front segments are exposed, and then quickly seizing the creature and withdrawing it by a slight pull. But this will not do; for although the larva is not attached to its case as a snail is to its shell, yet the last segment of the abdomen is provided with a pair of hooks, the free ends of which are directed forwards, and the larva holds on so effectually by means of these that it will often allow itself to be torn in two rather than submit to forcible eviction.

But there is a safer, less cruel, and far more effectual way of taking possession of the home. Take a very fine stem, or a stiff bristle, and attack the tenant from the rear. I must admit that this is a very inglorious procedure, but it answers our present purpose; and the larva, not being acquainted with this form of attack, hastily quits its tube.

We will not now concern ourselves with the peculiarities of the larva itself, but, for the present, examine the case. On splitting it open, we find that it is perfectly smooth within, for it is lined with a substance that looks like a very thin and delicate paper. It is really a silken lining, spun by the larva just in the same way as certain caterpillars spin their cocoons. It leaves the body in a fluid condition, and, while soft, is of a glutinous nature, so that foreign substances are easily attached to it. It also hardens under water, thus making the case rigid and strong.

It will of course occur to the reader that one of two alternatives is necessarily open to the larva as its body increases in size. Either it must quit the case now too small to contain it, and construct another of larger size; or it must enlarge the old one. There are a few species that adopt the former alternative, but the majority of them resort to the latter. They add to the larger end as occasion requires, and even cut off the superfluous portion at the small end, which is now too small to accommodate the terminal segments of the abdomen.

But, it may be asked, can the larva perform the latter feat without coming completely out of its home? Such a procedure would be extremely dangerous to the insect. Caddis larvæ are deemed a luxury by fishes and a host of other carnivorous aquatics, as anglers know well, these larvæ being in great request as bait; and it would not be long before the unprotected grub would be devoured by some hungry foe.

The answer is this. The case, although not very spacious within, is generally large enough to allow the insect to double and reverse its body, and so the work may be accomplished from within, the creature being perfectly protected as it performs its task.

It may be mentioned here that each of the different species of Caddises constructs a case after its own peculiar style, and generally shows a decided preference for certain materials of construction.

This being the case, it will naturally occur to the reader that each species must have a preference for a particular kind of locality where the necessary materials are to be found. Thus, the case just described, which is constructed of particles of fine sand, is made by a larva (*Sericostoma multiguttatum*) that invariably inhabits streams the currents of which are sufficiently strong to prevent the formation of a deposit of mud, and yet not sufficiently rapid to carry off a fine sand. Again, there are species that inhabit rapid currents, in which fine sand or light débris could not accumulate, and these utilise the fragments of a stony or gravelly bed for the construction of their habitation, and even sometimes attach their cases to large stones that they themselves may withstand the force of the stream.

But even in rapid streams there is generally a quantity of rooted vegetation, which is cut up by the mandibles of certain Caddis larvæ, and cemented together to form a case. Thus, a species called *Halesus auricollis* makes its case of fragments of vegetable matter, weighted with stones at the 'tail end,' and often fixes it to a large stone when the current is a rapid one.

It will be inferred from the above remarks that the nature of the case remains pretty constant for each species. So much is this so, indeed, that many species may be readily identified by a cursory inspection of their habitations.

Some species of the family *Phryganeidæ* make use of pieces of stick or stem, which they cut up into suitable lengths, and arrange them either spirally, or in longer pieces running parallel from end to end. Their cases are often smaller at one end than at the other while the larva is young, but of equal size at both ends at a later stage.

The several species of the genus *Limnophilus* employ a great variety of materials. Some use sticks and stems, some cut up dead leaves, while others use sand, small stones, and the shells of aquatic molluscs, and even, at times, the elytra of dead water beetles.

Few Caddis cases are more interesting than those formed wholly or partially of aquatic shells; and it is astonishing how easily quite a collection these shells can be made by the aid of the larvæ. I have met with ponds where hundreds of bottom shells, such as those of the genera *Sphærium* and *Pisidium*, could be taken in a few minutes by simply sweeping the Caddis larvæ from the weeds, and without the slightest occasion for disturbing the mud in which these molluscs lie. And the larvæ do not confine themselves to the empty shells of dead molluscs. In fact, on some occasions the cases are made up almost entirely of tenanted shells, the molluscs having to subsist as best they can while being dragged about from place to place by the grub that has appropriated their shells to its own use.

Live species of *Planorbis* are often captured in the same way by Caddises, and it is often amusing to watch the procedure of the molluscs as they attempt to follow their own inclinations. The mollusc will make an attempt to crawl away at a time when the larva is at rest, but it is not strong enough to move the heavy case; and just when the snail has succeeded in getting a foothold, and attempts to go its own way, the larva decides on an opposite course, and the poor snail is torn away from the object to which it had attached itself.

In addition to the shells already named, the smaller *Limnæa*, the freshwater limpets (*Ancylus*), and species of *Bithynia* and *Valvata* are all appropriated by Caddis larvæ for their cases.

The shells selected are almost invariably fixed with their flattest side turned inwards, and the same applies to the stones and other objects used in the construction of the cases.

Among the other materials employed for this purpose may be mentioned pieces of reeds and rushes, cut into suitable lengths; the seeds of rushes and other plants; and also dead leaves. The last named are sometimes cut up into small pieces and arranged spirally, or in longer pieces placed side by side, or are even used entire.

Some species are also more or less social in their habits, two or more larvæ living in a common home attached to a stone in the bed of a stream. Such homes are sometimes constructed of vegetable matter or other débris, or they may consist of little or nothing save the silken secretion from the glands of the larvæ.

Now let us examine the larvæ themselves. For this purpose we select one of the larger species, and drive it from its case by gently probing it from behind with a grass stem as before described.

One of the first features that strike us is the remarkable difference between the front and hind segments. The head and the thorax, which are the only parts that protrude from the case when the animal is walking, are protected by a hardened integument; but the segments of the abdomen, that are always protected by the case, are lighter in colour and very soft, and we can quite conceive that these grubs would be dainty luxuries for fishes.

The mouth is provided with a pair of mandibles, and just behind it, on the under side of the head, is the spinneret that communicates with the gland from which a viscid fluid is secreted.

The legs are strong, and are covered with the same hardened horny integument that protects the three segments to which they are attached.

The first segment of the abdomen has usually no appendages, but several of the following segments bear filamentous organs which lie closely on the back when the larva is out of the water, but float off and assume a feathery appearance when it is submerged.

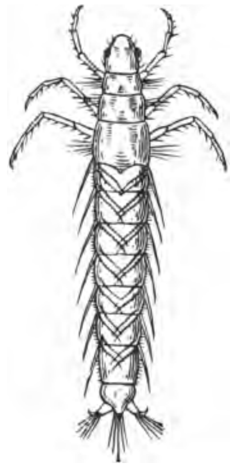

FIG. 236.—A CADDIS LARVA, ENLARGED

Each of the filaments is supplied with a branch of the tracheal system of the insect, and is really a kind of gill, through the very thin walls of which oxygen gas passes from the water.

It may be supposed that the creature, being normally confined rather closely in a narrow tube, would have only a limited supply of air passing over and around its breathing organs; but this is not the case. We have already seen that the case is generally of such a diameter that the larva can double its body within it, also that it is usually open at both ends.

Now, the larva causes a current of water to flow through the tube by gently undulating its abdomen. This motion is not incessant, but carried on at frequent intervals; and by this means the breathing filaments are bathed in a slow stream of fresh water.

But, then, how are these movements to be observed, seeing that the Caddis cases are usually quite opaque?

In the first place it may be noticed that a larva, deprived of its home and placed in a glass of water, will frequently wave its abdomen in the manner described, even though there may be no necessity for it under the circumstances. But this is not all, for it is possible to compel the creature to use transparent substances for the construction of the case, so that the motions of its body may be witnessed under more natural conditions.

Turn a larva out of its tube, and place it in a vessel of water containing no solid substances except what you have yourself introduced for building material, and it will soon commence constructing a tube of them.

Many very interesting results may thus be obtained, though I must say that I have not found all species equally ready to build under circumstances so unnatural to them. The commoner species of Phryganea which inhabit ponds and ditches almost everywhere, and some of the sand-builders of our ponds and rivers are very willing workers under such conditions, and in the course of a few hours will construct cases of almost anything with which they are provided.

If our object is to obtain amusement only, very pretty and striking results may be produced by supplying the larvæ with sands or small glass beads of different colours; and if they are transferred from one vessel to another during the operation, they may be made to complete their cases with substances of a different nature from those with which they started. But to return to the transparent cases to which we have above referred. These I have obtained as follows:

The larvæ, after removal from their cases, are placed in a vessel of clean water without any sediment. They are then provided with very thin plates of glass, such as may be easily obtained by heating the end of a piece of glass tubing in a blowpipe flame, blowing out a thin bulb, and then breaking it into little pieces of about an eighth of an inch or more in length. The pieces should not be too small, or the case produced will be too opaque to allow a clear view of the larvæ within. In fact, the larger they are the better, providing they are not too cumbersome for the insects to manipulate.

With cases produced in this way the larvæ may be watched with ease, and the undulations of the abdomen by means of which the water currents are maintained for breathing purposes rendered visible.

The method of 'spinning up' the case is also very instructive, and with close observation in a clear vessel, we can even distinguish the silken thread as it is worked from piece to piece while the case is being built up.

Some Caddis larvæ do not construct any case at all, but find a hiding place ready provided in the water. I have often found large larvæ within the hollow of a piece of stem which has simply been cut to a length adapted to that of the inmate.

In such instances it is necessary for the insects to quit their old dwellings when too small for their needs, and seek another of suitable size.

It is remarkable how unerringly a larva will often find its own case after having been expelled, even when placed in the midst of several similar cases, all of which are empty. To test this I have driven half a dozen larvæ from their tubes—all hollow stems of similar appearance and size; and, after marking one of them and isolating the larva that inhabited it, have put all the cases into one bottle, together with the larva in question. In nearly every instance the creature would search out its own home, instead of occupying the one nearest at hand, which would apparently have served its purpose quite as well.

A larva always re-enters its case head first, and if the case is equally large and also open at both ends it has no need to turn itself round after it is in. But many cases are much smaller at one end than at the other, and the larvæ which have been expelled from these will turn themselves round after entering, in order to bring their heads to the larger aperture.

Caddis larvæ are hatched from the eggs during the summer months, and are not full grown when the cold weather of winter sets in. But they are far less active during the latter period, and spend most of their time under the shelter of stones or in the mud or other sediment of the water in which they live. It is probable, too, that they partake of very little food during this period of inactivity.

We have spoken of these larvæ as vegetable feeders, but some few species seem to show a preference for an animal diet; and it is probable that some of them are entirely carnivorous.

These insects are often called Caddis Worms by the anglers who use them as bait, but it would hardly be necessary here to point out that they are quite distinct from worms—that there is none but a very distant relationship between the true worms and insects, the latter being distinguished from the former by their metamorphoses and by the presence of three pairs of walking legs.

When the winter is over, the Caddis larvæ resume activity, and grow rapidly till their full size is reached in late spring or early summer. They then cease to feed, and start making preparations for the changes they have to undergo.

At this period they secure themselves from the attack of their numerous enemies by sealing up the ends of their cases. But one end at least of the case must be in free communication with the water, since oxygen is necessary still for respiratory purposes.

Some species cover the ends of their cases with a silken network, while others partially seal them up by spinning together some pieces of the same materials that were used to construct the case itself. Some partially bury their cases in mud, leaving the front portion exposed for securing water and air.

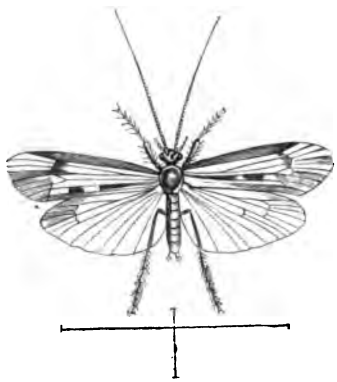

FIG. 237.—CADDIS FLY (*Limnophilus bicolor*), ENLARGED

A few days after this work has been completed, the larva casts its skin, thus revealing itself as a pupa, which may be readily recognised by its peculiar mummy-like form. The legs are now folded under the body, and the wings and other organs which mark the perfect state are all more or less visible.

Two or three weeks are now spent in a perfectly quiescent state; and when the time arrives for the final change, the insect again becomes active, breaks loose from the case that has protected it for so many months, and seeks out a convenient spot from which it can climb out of the water, sometimes even swimming by the aid of its legs, which, like the rest of the body, are now covered with the loosened skin that is soon to be cast off.

This is a time of great danger to the Caddis. All the carnivorous aquatic animals that spent the winter in a dormant or semi-dormant condition have now been called into activity by the genial sun, and their keen appetites keep them always on the alert for tender grubs of all kinds; and it is probable that a large proportion of the Caddis pupæ are seized by these hungry foes as they make their short journey from the deserted case to the surface of the water.

It is possible, too, that the danger is greater to the females than the males, for their bulky bodies, already full of eggs, must certainly give greater satisfaction to the hungry carnivores than the slender and comparatively empty bodies of the males.

The majority of species climb quite out of the water, and rest on the stem of a plant or on some other object to await the drying of the loose skin. This does not occupy much time, and the skin then splits, allowing the perfect insect to emerge. Then follows the expansion and subsequent drying of the hairy wings, after which the fully developed Caddis Fly, now a free child of the air, starts on its short life of sport and parental duties.

It has been observed that the pupæ of some species do not leave the water in order to pass through their final metamorphosis, but simply allow themselves to float on the surface, and, having emerged

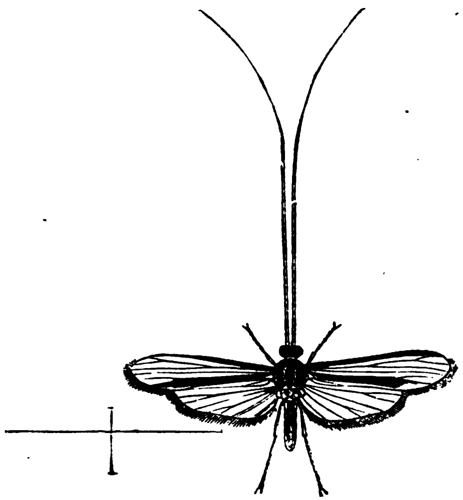

FIG. 238.—CADDIS FLY (*Leptoceros ochraceus*), SLIGHTLY ENLARGED

from the pupal skin, make use of this as a kind of raft on which to expose the wings to sun and air. This habit is common with gnats, and will be referred to again when we deal with those insects.

The female, after discharging her eggs, carries them about with her for a time. They are all in one mass, and surrounded by a covering of glutinous matter. She deposits them in water, sometimes walking down a submerged stem to accomplish her end.

As soon as the young larvæ are hatched they commence the work of tube-building. They are very active at first, and some species even swim with considerable dexterity at this stage, using their fringed hind legs something after the manner of a water beetle.

There are a good many species of Caddis Flies, a few of which are figured.

The illustrations given, together with the general features of the order, will be sufficient to enable the reader to know a Caddis when he sees one.

The Great Caddis Fly (*Phryganea grandis*), shown in fig. 212, is one of an extensive genus. The others are illustrations of smaller species. The latter are slightly enlarged, but the natural size of the insects is shown.

Aquatic Diptera

The *Diptera*, or two-winged insects, include several species whose earlier stages are spent in water, and of which the perfect forms are to be found hovering over water or flying in the neighbourhood of ponds and ditches.

The hind wings of dipterous insects always exist in a very rudimental condition, being represented by mere scales, or by a pair of delicate filaments which terminate in a knob resembling the head of a pin. The latter are often termed *halteres*, *balancers*, or *poisers*, which names have arisen from the supposition that the organs in question assist in steadying the insect while on the wing; but it is difficult to conceive how such a function could be performed by organs so small and so short compared with the body and its larger appendages.

The functional wings are attached to the middle segment of the thorax, and therefore correspond with the front pair of four-winged insects. They are membranous, and usually clear and transparent, but often marked with coloured spots or patches; and the membrane is supported by a few nervures.

The mouth is suctorial, and constructed on the same plan as that of the *Hemiptera*, the labium being prolonged into a tube through which the insect sucks up the juices on which it feeds.

In the *Diptera* the metamorphoses are complete and well marked, and the pupa is generally quiescent, but sometimes it is as active as the larva. The larva is a footless grub, in many cases commonly known as a maggot. The segments are usually well marked, but often there is no distinct head.

Although we are directly concerned only with those species which are of aquatic habits, yet I would recommend those readers who are not acquainted with the general characters of the *Diptera* to examine the common Blow Fly, and watch it through its different stages. This well-known insect is easily obtained throughout the whole of the summer, and the rearing of it is a matter which presents not the slightest difficulty. Simply expose a small piece of meat of any kind to the air, placing it on a bed of wet sand. In a short time the clusters of eggs may be observed, and soon the young larvæ will commence their ravages on the store of food provided for them. The pupæ, which in this case are quiescent and encased in a brownish covering, may be afterwards dug out of the sand into which the larvæ burrow when fully fed; and the emergence of the perfect insect may be watched, providing the observer happens to be on the alert at the right time.

We will now deal with some of our aquatic *Diptera*.

The Gnat (*Culex*) and Allied Insects

One of the most interesting of the aquatic *Diptera* is the Common Gnat (*Culex pipiens*), the merry flight of which is well known to everybody. There are many, however, to whom the familiar name recalls something more than a lively movement in the still summer air. It suggests sensations which leave a more lasting impression—a gentle buzzing sound in the neighbourhood of one's ears, followed by a sharp stinging sensation on some tender unprotected spot.

But the insect is as interesting as it is troublesome; more so, indeed; and one forgets the tantalising 'bite' of the creature when its exquisite beauty is displayed beneath the lens.

The wings are long and narrow, and the nervures are clothed with minute scales, something like those which cover the wings of most of the *Lepidoptera*. These scales are marked with ridges, which project beyond the edge, giving a spiny appearance; and they are not restricted to the nervures of the wings, but also clothe the body and the limbs. Like those of the *Lepidoptera*, they are easily removed by means of a soft brush, and may then be transferred to a glass slip for examination under the microscope.

The body itself is somewhat club-shaped, and the legs are very long and slender.

It is the head of the Gnat that demands our greatest attention, however; and more especially the wonderful arrangement of organs that form the weapon of offence. But it must be observed that the female only is capable of inflicting pain, and the following remarks apply to her alone.

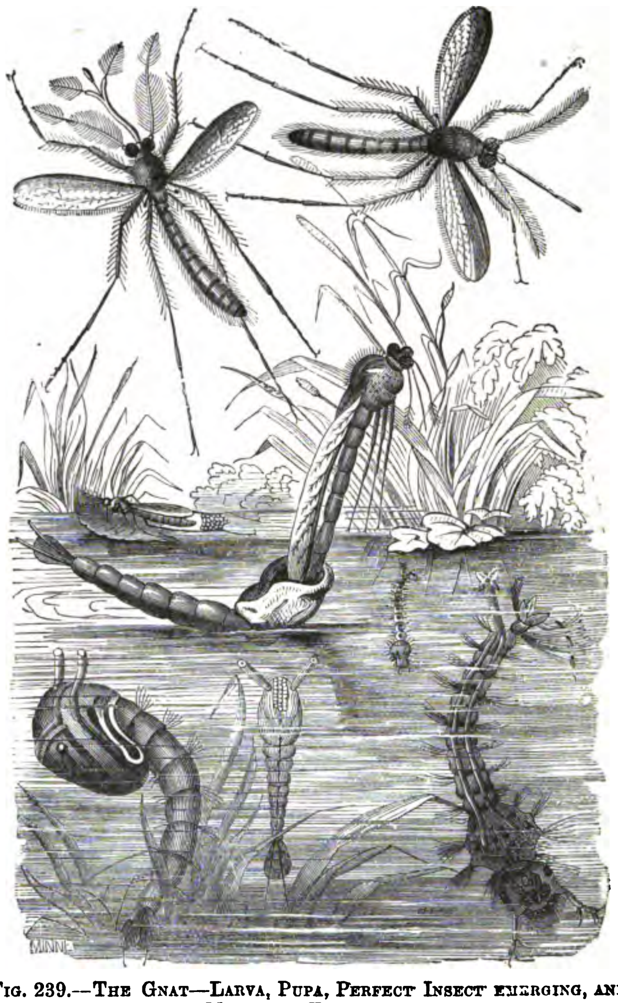

FIG. 239.—THE GNAT—LARVA, PUPA, PERFECT INSECT EMERGING, AND THE MALE AND FEMALE FLYING

The labrum, or upper lip, is prolonged into a stiff bristle-like tube, slit throughout its length behind, and used for suction. The lower lip (labium) is a long, soft, flexible sheath, grooved in front to accommodate the mandibles and maxillæ. The former are two long and slender lancets for piercing, very sharp and barbed at the tip. The latter also constitute a pair of slender lancets, equally sharp, but instead of being barbed they are provided with a sawlike edge at the tip.

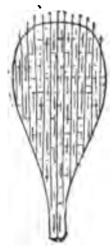

FIG. 240. SCALE OF THE GNAT

In addition to these four piercing organs there is a fifth lancet, sometimes called the tongue, but which is really a prolongation of the middle portion of the labrum. Thus the female gnat is provided with five separate lancets, guided and protected by the labrum above and the labium below. She thrusts them into the flesh of her victims, and then sucks the blood from the small wound thus made.

The method of suction is interesting. The œsophagus has the power of enlargement, thus serving the purpose of an exhausting pump. When it expands, it decreases the pressure in the digestive tube behind the mouth, thus encouraging the flow of fluid into the mouth from without.

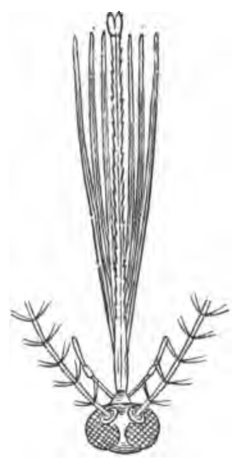

FIG. 241.—ORGANS OF THE MOUTH OF THE FEMALE GNAT, ENLARGED

As with some of the water bugs (*Notonecta* and *Naucoris*), the pain produced by the 'bite' is so sharp that it is difficult to believe that it is produced by mechanical irritation only, without the injection of an irritant poison. Yet this is probably the case, for as yet no poison gland seems to have been traced. It is probable that the intensity of pain is due to the action of the barbed point of the mandibles, and of the sawlike edges of the maxillæ.

The male gnat is incapable of inflicting pain, the parts of the mouth, so highly organised in the female, being undeveloped in this sex. And it is difficult to understand why the female herself should be thus armed; for not only does it appear probable that only a very small proportion of the myriads of gnats which swarm in the air ever pierce the skin of an animal, but gnats also abound in desolate subarctic regions where hardly an animal is to be seen. Still we are well aware that the female gnat *can* 'bite,' and sometimes *does* do so; and it is also possible that her mouth organs are used for extracting the juices from vegetables as well as from plants.

We must not omit to notice, however, the beautiful form of the antennæ of the male. These organs are composed of fourteen separate joints, each one of which has a radiating cluster of long and thin hairs, so that the whole looks like a very delicate feather. The female also has a pair of antennæ, but the tufts of hairs are so short that the organs are comparatively inconspicuous.

The female gnat lays her eggs on the surface of the water, and it is very interesting to watch the operation, as well as that of glueing the eggs together.

She usually alights on the surface of the water, and immediately crosses her hind legs, and supports herself on the other four. Her weight is not sufficient to cause the feet to break through the surface film, and, if the water is perfectly calm, four little depressions may be observed where the feet rest on the water.

It generally happens that the gnat has to make many movements before quite satisfied as to the suitability of a spot for her purpose, and so she may be seen walking on the surface of the water or on floating weeds in search of a favourable locality. Her movements on the water itself are very awkward, compared with those of the water gnats and pond skaters, for she proceeds by a series of laboured jerks, generally using her wings as well as the two pairs of legs.

The spot usually chosen is either near to a floating weed or other object, or else close to the margin of the pond. She is thus enabled to support the front pair of legs on a solid substance, and sometimes the second pair also; but the latter often have no other support than the water itself.

The hind legs remain crossed and free in the air, and serve to guide the eggs into the required positions.

The eggs are cylindrical in form, but taper off at one end, and are provided with a lid at the other; and each one is covered with a sticky substance which soon dries on exposure to air. These are all arranged side by side with wonderful regularity, the similar ends being placed together; and the whole cluster, numbering from two hundred to three hundred, is built up into a little boat or raft, with the pointed ends at the upper, concave side, and the lids forming the convex surface below. The raft thus formed is only about three-sixteenths of an inch in diameter, and is left floating on the surface of the water.

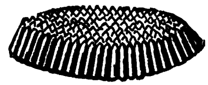

FIG. 242.—THE EGG RAFT OF THE GNAT, ENLARGED

It is in itself such an interesting object that we strongly recommend the young pond naturalist to procure one for examination and experiment; and there is no reason, too, why he should not watch the process of building.

For this purpose there is no necessity to travel away from home. Simply place a tub of water in a sheltered corner of the garden, throw into it some duckweed or other aquatic vegetation, and let it remain undisturbed.

It will not be long before the gnats will find the accommodation thus provided, and a little patient observation will now be well rewarded. It should be remembered, however, that these insects usually deposit their eggs early in the day, before the sun is very high; though in dull weather I have often seen them thus engaged up to midday.

It will be noticed that the peculiar nature of the egg raft provides for a free exposure of the eggs to the atmosphere—a condition probably absolutely necessary for the development of the young larvæ, and also allows the newly hatched insects to pass directly from the egg cases into the water that forms their home.

It is wonderful, too, how constantly these conditions are maintained in defiance of the natural forces which tend to disturb them. To prove this, blow a current of air on the surface of the water on which an egg raft floats—disturb the water as you will, and the raft maintains its position; or, if so roughly used that it is overturned, it rights itself again like a lifeboat.

Again, push the raft under water, and still the conditions are practically the same, for the water, instead of penetrating into the spaces between the upper pointed ends of the eggs, leaves a film of air over the whole surface, shining like a layer of quicksilver. Then release the raft, and immediately it rises to the surface, rights itself if in the wrong position, and the bubble that covered the upper surface then bursts, leaving that surface perfectly dry and free.

Let us now examine the larva of the gnat; and for this purpose we procure a few larvæ from a stagnant pool or ditch, or a waterbutt, and place them in a bottle of clear water. They are limbless creatures that move about in the water by wriggling their slender bodies.

When at rest they are suspended, head downwards, from the surface film of the water, in which position the breathing apparatus is exposed to the free air, while, at the same time, the head is directed downwards in search of food. The head is provided with hairlike filaments, by the movements of which currents of water are made to carry particles of food towards the mouth.

The segments of the abdomen are all distinct, and at the eighth one the body is bent. At the same point a cylindrical tube branches off from the abdomen in such a manner as to give the end of the body a bifid appearance.

The tube to which we refer is connected with the tracheal system of the insect. It contains two air tubes, continuous with the two main tracheal trunks that run through the body; and when the larva is at rest, the extremity of this tube is open to the air, just at the surface of the water.

If you rap the table on which the bottle containing the larvæ rests, the larvæ will detach themselves from the surface film, and allow themselves to sink, thus showing that they are heavier than the water.

And now we have to solve the problem of the creature's suspension—to find out how a larva whose body is heavier than its own weight of water can suspend itself at the surface without attachment to any solid object.

A close examination of the surface of the water where one of the larvæ is suspended will show that the surface film of the water is actually pulled down a little way by the weight of the insect. We may also observe five little valves at the orifice of the breathing tube. These are not easily wetted by water; so that while the larva is thus suspended from the film all round the exterior of the valves, the orifice between communicates freely with the atmosphere.

When the larva wishes to descend, it closes the opening of the tube by bringing the five valves together, thus releasing itself from the pull of the film, and then its body sinks in virtue of its superior specific gravity.

It never remains below for any length of time together; but, as soon as the disturbance that drove it to the bottom ceases, it rises by wriggling its body, keeping the valves of its breathing tube close together all the time. When it reaches the surface it thrusts the valves through the film and opens them; it then remains perfectly stationary, allowing its body to sink and hang by the film, the contractile power of which pulls the valves upward and outward on all sides.

The larva of the gnat is so transparent that it becomes a very interesting object when viewed through a lens or under the lowest power of a compound microscope. The distribution of the tracheal tubes can be easily made out, not only the main trunks, but also the finer divisions which ramify into the different segments of the body. The digestive tube is rendered particularly conspicuous by its dark and opaque contents, and the contractile vessel that serves the purpose of a heart is also distinctly visible.

The larva undergoes several moults during its growth, and the last one reveals it in the form of a pupa. But how the creature has changed! The organs of the future fly, some of which were to be seen even in the transparent larva, are now well developed, though as yet encased. The head with the antennæ and mouth organs, and the legs and wings of the future fly, all together form a great rounded mass, from which the comparatively narrow abdomen extends; and each of the appendages is ensheathed in its own case. The pupa is also provided with a pair of leaflike swimming organs at the tip of the abdomen.

But the most remarkable change is perhaps that which has taken place in the respiratory system. The tracheal system no longer opens at the eighth segment, but by means of two curved tubes on the back of the thorax. Hence we find the pupa suspended at the surface in a position very different from that assumed during the larval stage. The insect, though not now quiescent, no longer requires any food, and hence there is no longer any necessity for it to have its head directed downward in the water. Again, the insect is shortly to assume its winged state, and we may therefore reasonably expect to find it resting in a position that will allow it to emerge direct from the pupal skin into the air. This is really the case, for its position is such that the back of the thorax—the part where the skin splits—is close to the surface and directed upward.

In this position, too, the mouths of the two thoracic breathing tubes are flush with the surface of the water, and the water is no longer kept out by the action of five valves, as during the larval stage, but by means of a number of very fine hairs, between which the water cannot penetrate.

When the time is ripe for the final metamorphosis, the skin splits, and the insect soon extricates its head and thorax through the opening. The legs, wings, and other appendages are all withdrawn from their respective cases, and finally the abdomen becomes free.

The newly emerged gnat now requires a foothold until the wings are sufficiently dry and rigid for the first flight. This is provided by the old pupal skin, which, being empty and very light, serves the purpose of a raft; and on this the gnat rests for a short time, while the drying is in progress.

The term 'gnat' is often applied, or rather misapplied, to certain insects of another genus, called *Chironomus*, and popularly known as Midges. These belong to the family *Tipulidæ*, which includes the well-known 'Daddy-long-legs.'

They may be seen flying about in clusters in our gardens, especially in the neighbourhood of ponds, ditches, muddy streams, and rainwater butts, such being the natural homes of their larvæ; and they frequently stray into our houses.

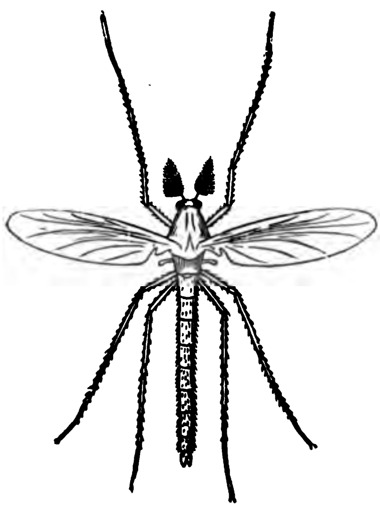

FIG. 248.—*Chironomus*, ENLARGED

Chironomus so closely resembles the gnat in general appearance, that there is some little excuse for the mistake above referred to, but yet there are some important differences to be detected on a close examination. The female has no piercing and sucking organ like that of the female gnat; in fact it takes no food of any kind. Also, there are no scales on the nervures of the wings of *Chironomus*; and the insect rests on its second and third pairs of legs, keeping the first pair raised, and crossed one over the other. The male may be distinguished from the female by its feathered antennæ.

The eggs of *Chironomus* are laid on the surface of water, and, like those of the gnat, seem to require exposure to air. As they are often deposited on running water, it is essential that they should be fixed in some way or another, so that they may not be carried away by the current; hence we find them attached to floating objects, or to fixed objects just at the surface level. They are laid in chains, varying from a quarter of an inch to nearly an inch in length, or in round or oval masses, according to the species. They are covered with a glutinous substance, like those of caddis flies; but in the case of *Chironomus* this substance swells out considerably by the absorption of water, forming a jelly-like protective covering. This substance, too, is so clear and transparent that the development of the young larvæ may be watched with the greatest of ease.

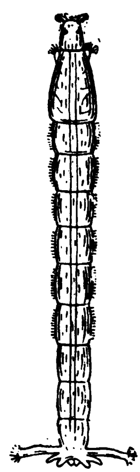

Fig. 244.—A 'Blood-worm,' viewed from above, enlarged

The larvæ are wormlike creatures, about three-quarters of an inch in length when fully grown, and of a bright scarlet colour. They are used largely as bait by anglers, to whom they are known by the name of Blood-worms.

They must be familiar objects to all who have any acquaintance with the open water-butt or who have ever dredged a little mud from a stagnant pool or ditch. They live in burrows which they excavate in soft mud, or in the spaces between the decaying leaves that so often cover the bed of standing or slow-running water. In either case the particles of the substance surrounding them are held together by means of a silky secretion from the salivary glands.

The burrows are always open at both ends, and thus the larvæ are enabled to feed on any suitable substance that comes within their reach while their soft bodies are almost entirely concealed. At the same time they set up water currents through the tubes for respiratory purposes by undulatory movements of their bodies, as do the larvæ of caddis flies.

It will be noted, however, that while the caddis larva generally lives in a portable case, the 'bloodworm' lives in a fixed home, and therefore cannot travel in search of food without exposing itself. It is probable, too, that the 'bloodworm' is often compelled to leave its home in order to obtain sufficient air for its respiration, since it generally inhabits the mud of very stagnant water, in which much carbonic acid gas must necessarily be produced by the decomposition of vegetable matter. This will probably account for the fact that the larva often leaves its burrow and swims about freely in the water nearer to the surface. And, having no appendages adapted for swimming, it progresses by vigorously looping its body, first on one side and then on the other.

Although the colour of the larva is so deep, yet the body is so transparent that its internal organs are plainly revealed by transmitted light with the aid of a low magnifying power. Its air tubes are not nearly so apparent as in the case of the larva of the gnat; in fact the tracheal system is only slightly developed, and the 'bloodworm' probably obtains most of the air required for the aëration of its crimson blood by direct absorption through the soft structures of its body. The dorsal heart, however, may be seen pulsating most distinctly. It must be mentioned, by the way, that the larvæ of some species of *Chironomus* have colourless blood, and therefore colourless bodies.

The 'bloodworm' has a pair of short legs attached to the first segment of the thorax, and these are adapted for prehension, being provided with a circle of little hooks. Like the caddis larva, it has also hooked appendages at the extremity of the abdomen, by which it can hold on to the silken lining of its burrow. On the last segment but one it has four tubular appendages, probably connected with the respiratory function.

The food consists of decaying organic matter, which is seized and bitten by a pair of powerful mandibles. The head has also a pair of jointed antennæ.

The pupa of *Chironomus* is very much like that of the gnat, the head and thorax, together with their appendages, forming one large rounded mass; but instead of the trumpet-like breathing tubes, it is provided with tufts of hairlike filaments that communicate with the tracheæ, now more highly developed.

The final metamorphoses very closely resemble those of the last genus, and therefore need not be detailed here.

We have several gnatlike insects with aquatic larvæ, but the exigencies of space will not allow anything more than a brief description of one other.

It often occurs that we find abundance of life in the aquarium into which we have thrown the miscellaneous haulings of a day's pond work—life which was not seen at all during the cursory examination in the field, either on account of the minuteness of the creatures concerned, or because of the extreme delicacy and transparency of their bodies.

Among these we often find the larva of a little fly belonging to the genus *Corethra*, which was taken from among the weeds or partially submerged grass of a stagnant pool or ditch.

So transparent is this larva that it may often be overlooked even in the aquarium, and the startling suddenness with which it disappears or makes its appearance has earned for it the popular name of the 'phantom larva.'

If it is required to examine its general characters and movements, it should be removed from the aquarium by means of the dipping tube, and then transferred to a small, shallow glass vessel, so that it may be easily inspected from above by the aid of a lens.

For a short time it remains perfectly motionless and suspended horizontally in the water, but just as we are beginning to make out some of the details of its structure it suddenly darts away with such speed that the movement cannot be closely observed. However, we discern it again, about three-quarters of an inch from its former position, and just as motionless as when we first commenced our observation.

A careful examination shows that these movements are produced by a very sudden bending of the body, unaided by appendages of any kind save a finlike organ composed of a number of plumed bristles placed vertically beneath the hinder portion of the abdomen.

The larva has no limbs, and the body is so clear and transparent that the internal organs may be seen distinctly by transmitted light.

The most striking feature at first sight is the presence of two pairs of conspicuous black spots, one pair in the segment next the head, and the other in the eighth. These are really air cavities, and seem to serve a double purpose. Being connected with the two tracheal trunks, they have undoubtedly something to do with respiration; but they also serve the purpose of a couple of floats to assist in maintaining a horizontal position in the water.

The larva has no spiracles, and no external organ like the gills of some aquatic insects, but seems to obtain the air it requires direct from the water through the soft structures of the body.

In addition to these air cavities one may see the digestive tube, the pulsating tubular heart, and the chain of nerve ganglia, all visible through the clear body.

The larva is a predaceous creature, feeding on various small insects and crustaceans, which are seized by its prehensile antennæ, and afterwards manipulated by a pair of handlike jaws.

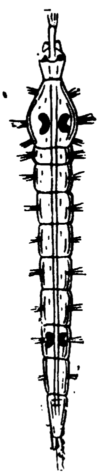

FIG. 245.—LARVA OF *Corethra*

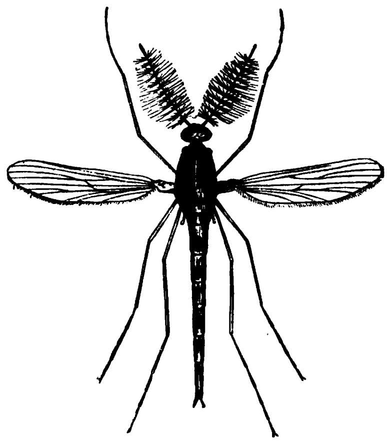

FIG. 246.—THE PERFECT *Corethra*

The pupa is much like that of the gnat, save that the rounded mass formed by the head and thorax is not so large in proportion to the size of the body, and, like the pupa of the gnat, it possesses a pair of breathing tubes which stand out from the thorax, and it rests at the surface of the water in a vertical position, awaiting its final change.

It has a broad and flattened tail, which reminds one of the *telson* of the crayfish. It is also used in a similar manner, for when the pupa is alarmed it suddenly bends its body, raising the tail and thus causing itself to descend by a series of jerks, of course travelling tail foremost.

The perfect insect is much like the two preceding, and may be easily mistaken for a gnat. It has many-jointed antennæ, which are fully plumed in the male sex.

Other Aquatic Diptera

We have now to deal with a few dipterous insects that are of a very different build from the preceding. Their bodies are stout, and the antennæ very much shorter in proportion, and they resemble bees and 'bluebottles' more than gnats. They are also strong on the wing, and often exhibit very brilliant colours.

Our first example is the Common Chameleon Fly, of the genus *Stratiomys*. Its body is broad and rather flat. The ground colour is black, relieved by bright yellow markings, and the antennæ are composed of only three segments.

Fig. 247.—*Stratiomys chameleon*

This fly is somewhat beelike, and may often be found sucking the sweet juices of flowers in the neighbourhood of ponds. Its flight is rapid, but not long, and it may be easily followed up from one resting place to another.

It does not lay its eggs on the surface of the water, after the manner of the species previously described, but deposits them on the leaves of semi-aquatic plants that stand up above the surface.

The larva is a very strange creature. It is a flattened and legless maggot, thicker in the middle, and tapering off towards both the head and the tail, the latter end being very long and slender. The segments of the fore extremity are short, but they increase uniformly in length towards the tail.

The length of the larva may vary from one to two and a half inches, according to the creature's own desire, for the segments of the body are capable of a telescopic motion, the front segments retreating each within the one behind it, and each of the others into the one in front of it. Thus when the larva is alarmed both extremities approach one another, causing the body to become shorter and thicker.

The colour of this larva is very variable, but is generally some shade of green, yellow, or brown—colours which tone well with the surroundings, and consequently are more or less protective. Its skin is tough and leathery.

It inhabits stagnant pools and ditches, sometimes creeping in the mud, dragging its body along by means of its mouth, probably assisted to some extent by the short bristles which project backwards from each of the segments. It also swims at times by alternately doubling and extending its flexible body, but its progress is rather slow. Usually, however, it rests at the surface, suspended from the film by the tail in a manner to be described presently, and keeping up a circulation of the water by means of the short appendages of the head for the purpose of securing the small aquatic creatures that form its food.

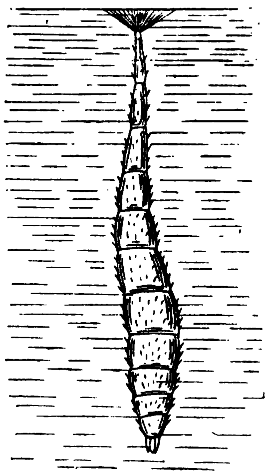

FIG. 248.—LARVÆ OF *Stratiomys*

The tip of the tail is furnished with from twenty-five to thirty radiating feathered bristles, which can be spread out or brought closer at will. As long as the larva is swimming, or crawling in the mud at the bottom, all the tail filaments are held together in such a manner as to form a little cup, which always encloses a bubble of air for respiration while the creature remains submerged.

When it rises to the top for repose, it thrusts the top of the cup through the surface film, and immediately spreads out the bristles into the shape of a shallow cone. The bubble previously enclosed thus escapes, and the cavity is in free communication with the atmosphere; and since the filaments are not readily wetted by water, they are pulled upwards and outwards by the elastic film, thus enabling the larva, which is heavier than its own weight of water, to suspend itself head downwards.

It will be surmised from the above description that the larva of *Stratiomys* has its tracheal system communicating with the air enclosed by the filaments of the tail. It has spiracles along the sides of the body, but these are not functional.

This insect does not pupate in the water, but burrows into the soil near the water for this purpose. The larval skin then becomes loosened on all sides; but instead of being thrown completely away at the tail, as is the case with most insects under the same conditions, it remains intact, even to the filaments of the tail, and so forms a loose protecting covering over the pupa.

As a rule the pupa of an insect is smaller than the full-grown larva; but in the case of *Stratiomys* the difference is very great, so that the pupa, which is quiescent, lies in a case which is not half filled by the occupant.

The pupal condition lasts only for a few days, at the end of which time the perfect insect breaks through both its pupal and larval coats and finds its way into the air.

Another insect (*S. furcata*) of the same species is figured here. It is very similar to *S. chameleon* in colouring, and its life history is also much the same.

Fig. 249.—*Stratiomys furcata*

Fig. 250.—*Eristalis tenax*, SLIGHTLY ENLARGED

Our last example of the *diptera* is the Drone Fly (*Eristalis tenax*), the remarkable aquatic larva of which is commonly known as the Rat-tailed Maggot.

To find this larva you must search in the smallest, muddiest, and most putrid waters, the black mud of which consists largely of decomposing organic matter. The net must be made to scrape up the mud close to the banks, where the water is not more than two or three inches in depth.

It is not very convenient to observe the habits of this larva in its native haunts, both on account of the nature of its home and because of its habit of burrowing into the mud; but if the dredgings of the pond, mud and all, be transferred to a shallow dish or tub kept in the garden and covered with an inch or two of water, the water, black and thick at first, will soon deposit its sediment, becoming sufficiently clear to enable one to watch the movements of the insects.

At first they seem to be unsettled and restless, swimming about clumsily in the muddy water, or creeping about on the bottom or sides of the vessel. But after a time, when the water is clear, we see them partially buried in the odorous mud, with their long and slender 'rat tails' standing up perpendicularly and just touching the surface.

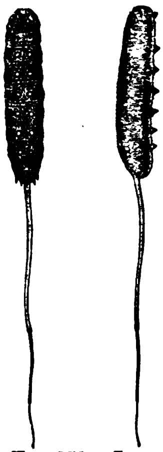

FIG. 251.—LARVA OF *Eristalis tenax*

Now tap the vessel that holds them, and immediately all the tails disappear, but only to be thrust out again as soon as the alarm is over. All the time the cylindrical bodies are buried deeply in the putrid mud from which the larvæ are sucking out the decomposing matter which forms their food.

It might be supposed that the *Eristalis* larvæ have something to do with the cause of the putrid condition of the mud in which they live; but this is not so. In fact, the reverse is the case; and there is reason to believe that the mud they inhabit would be far more putrid than it is were it not for their presence, for they are almost incessantly sucking up the decomposing particles of organic matter to which the water owes its offensive condition, and converting them into the harmless living substance of their own bodies.

If we withdraw one of the larvæ from its miry bed, cleanse it with running water, and then drop it into a glass of clear water for examination, we shall be able to discern its form and to observe its movements. It is then seen to be of a dull greyish colour and destitute of true legs, but provided with seven pairs of very short retractile feet, something like the pro-legs of a caterpillar. These feet are circular in form, and each has a double circle of little hooks adapted for prehension, and therefore useful for creeping.

The most interesting feature of the larva, however, is undoubtedly the tail, which consists of two distinct parts—an outer retractile tube, which is a direct prolongation of the skin of the body, and a finer threadlike organ that telescopes within it.

This arrangement allows the larva to maintain a communication with the atmosphere in water of different depths, at the same time keeping its body in the mud whence it derives its food. If we place the larva in very shallow water the length of the tail is so adjusted as to reach the surface; and by gradually adding to the liquid, we may cause the creature to protrude it more and more, till at last it reaches its greatest possible length—more than two inches—and is almost as fine as a hair at the end. If we now continue to increase the depth of the water, the insect is unable to breathe as long as it remains at the bottom, and so it endeavours to creep up the sides of the vessel, keeping its tail extended to the utmost limit as if feeling for the air, and will not rest till the surface of the water is reached.

The breathing tube is transparent, and if we examine it with the aid of a suitable magnifying power we can discern two tracheal tubes running throughout its length. These are straight when the telescopic tail is extended to its greatest length, but become neatly folded into a series of loops when the tail is retracted. They communicate with a pair of large dilated air tubes that run through the body, and terminate in a pair of closed spiracles by the head.

The movements of the telescopic tail, and the manner in which the two air tubes become folded as the tail is retracted, are both easily seen in the body of a young larva, which is sufficiently transparent to enable the internal organs to be discerned. If we place it in a very shallow glass cell filled with water and examine it with a moderately low power, we can cause the tail to protrude merely by the application of a gentle pressure on the body; and each time the pressure is relieved the tail recedes, thus enabling us to watch the manner in which the air tubes are folded.

When the larva is full grown it creeps out of the water, and burrows into the soil in the neighbourhood of its pond. Its skin then gradually becomes loosened from the body, and hardens so that it forms, together with the earthy matter that adhered to it while yet soft and moist, a kind of cocoon, within which the pupa rests for a few days.

The perfect insect is very swift on the wing, and may be seen throughout the summer flying from flower to flower, sucking out the sweet juices after the manner of a bee. What a contrast is this with the habit of the larva! The latter delighted in the most foulsome mire and fed on its very essence; but now the selfsame insect, changed from an ugly maggot to a beautiful fly, seeks the combined fragrance and sweetness of the choicest flowers.

We have spoken of this insect as beelike, but this similarity is not confined to mere form and colouring, for, as we have just seen, the insect is beelike in its habits. For this reason it is very seldom touched except by the comparatively few persons who know how to distinguish between the dipterous, stingless insects and the hymenopterous insects, some of which are armed with a sting. And the resemblance, which of course serves to protect the fly against many of its enemies, is still further increased by a strange habit which the fly exhibits when caught. Hold one by taking its wings between the finger and thumb, and it will double up its abdomen in the same threatening manner that a bee or wasp would; and so determined are its efforts to apparently make the tip of the abdomen touch the skin, that it is difficult to convince the uninitiated that the fly really has no sting.

The specific name (*Tenax*) of this insect has reference to the power with which it can hold on by its feet.

Aquatic Lepidoptera

Those who are but little acquainted with the *Lepidoptera*—the order of scaly-winged insects commonly known as Butterflies and Moths—may be surprised to hear of aquatic species among them. We are all familiar with the fate of the moth that accidentally falls into a pond or into an open waterbutt. We have seen it struggling in vain on the surface till the beauty of its wings is greatly impaired. We know, too, the fate of the poor caterpillar who meets with a similar mishap. Whether it sinks or floats, its body becomes wet and its spiracles filled with water, so that breathing becomes impossible and the creature is soon drowned.

Hence our surprise on learning for the first time of caterpillars that are capable of living beneath the surface of a pond, and of moths that can even creep down the submerged stems of aquatic plants, and return into the air with wings quite dry and unsoiled.

It should be known, however, that of the many hundred species of British Butterflies and Moths, only five have aquatic tendencies. These we shall briefly describe; but before doing so, we must become acquainted with the distinguishing characteristics of the order to which they belong.

If we handle a Butterfly or a Moth we observe that a dry dust easily becomes detached from its wings. This dust, on examination under the microscope, proves to be little scales of a definite form

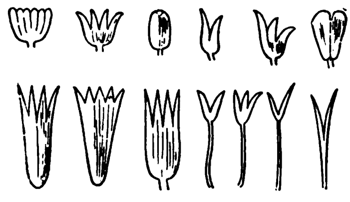

FIG. 252.—SCALES FROM THE WINGS OF BUTTERFLIES, MAGNIFIED

that vary with the species as well as with the part of the wing from which they are removed.

Then, if we examine the partially denuded wing we find that the scales are neatly and regularly arranged in rows, each individual scale being attached by means of a short stalk.

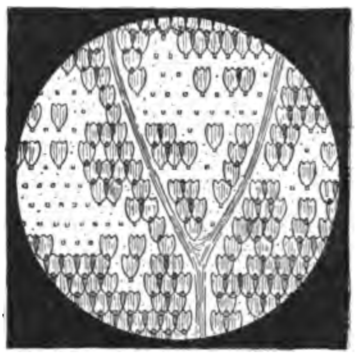

FIG. 253.—PORTION OF THE WING OF A BUTTERFLY FROM WHICH SOME OF THE SCALES HAVE BEEN REMOVED, MAGNIFIED

Further, the wing may be completely denuded by means of a soft brush, and then it is seen to consist of a thin transparent membrane, supported by branching nervures.

In the *Lepidoptera* the metamorphoses are complete. The larva, commonly known as the caterpillar, has a more or less cylindrical body of thirteen segments, counting the head as the first. The next three segments correspond with the segments of the thorax of the perfect insect, and each one bears a pair of legs with hooked claws. Some of the other segments have membranous and retractile 'pro-legs,' each of which is armed with a circle of minute hooks, enabling the larva to hold on with great tenacity. The

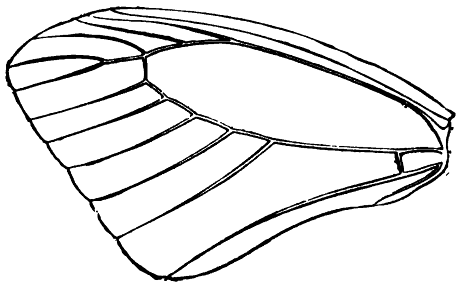

FIG. 254.—WING OF A BUTTERFLY, THE SCALES HAVING BEEN REMOVED

number of pro-legs varies, but is commonly ten. At the sides of several of the segments may be observed the stigmata or spiracles—the openings by which the tracheæ communicate with the atmosphere.

The head is provided with a strong pair of jaws which are used for biting the food, and also, in some cases, for breaking up substances that are used in the construction of cocoons. There are also a pair of very short and inconspicuous antennæ, six pairs of simple eyes, and a spinning apparatus consisting of a pair of glands, the viscid secretion of which passes out through a duct that opens just under the mouth.

Caterpillars undergo a series of moults, and when fully grown seek a secure spot in which to change. Those of the Butterflies do not spin a cocoon of silk, though they often suspend themselves from a silken carpet and make themselves secure by fixing a cord of silk round the middle of the body. The larvæ of Moths, on the other hand, often spin the most beautiful silken cocoons, or bind together bits of leaves, particles of earth, or fragments of wood, &c., using the secretion of their silk glands for this purpose.

The pupæ of the *Lepidoptera* are quiescent, though many of them move vigorously at times, especially when irritated; and they are protected for the time being by a hardened, horny skin in addition to any covering they may have prepared for themselves.

When the time for the final change arrives, the pupal skin splits on the back of the foremost segments, and the perfect insect, still with undeveloped wings, quits its case, and immediately seeks a place where it can suspend itself while its wings expand and dry.

The wings grow rapidly, being often fully developed in a few minutes; but they are still moist and limp, and quite useless for flying. They soon become dry and rigid, however, and the insect is then ready for its first flight.

The chief distinguishing feature between Butterflies and Moths is to be found in the antennæ. Those of the former are clubbed or knobbed at the end, while those of the latter, though very variable in shape, are always more or less pointed at the tip. All Butterflies are diurnal in their habits, while Moths are usually nocturnal. Butterflies, too, are often described as being more brightly coloured than Moths, but it must be remembered that there are many of the latter displaying the most gorgeous colours, while some of the Butterflies are decidedly dingy.

We will now briefly consider our aquatic species of this order. These belong to a family called the *Hydrocampidæ*, and the insects themselves form a little group of Moths popularly known as the China Marks, on account of the nature of the pattern on the wings.

They are slender-bodied insects, with long and slender legs provided with long spurlike bristles, and the females are larger than the males.

Our first example is the Small China Mark (*Cataclysta Lemnata*), a pretty little moth that is common almost everywhere, and may be seen flying among the vegetation on the margins of ponds from June to August. The wings of the male are white, with a small black central dot and dark hind margin; and the dark band of the hind wings contains five minute but bright silvery dots. The forewings of the female are brownish, with darker markings. The hind wings are clouded with grey, and, like those of the male, have small silvery spots near the hind margin.

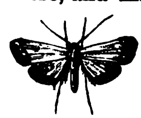

FIG. 255.—*Cataclysta Lemnata*

The larva is of a brownish colour, and feeds on duckweed. It makes a case something after the manner of the caddis larva, by spinning together the fronds of the duckweed; or sometimes it will utilise a piece of a hollow stem found floating in the pond.

During the earlier part of the larva's existence it is capable of deriving air from the water; but after a time its stigmata become functional, and it then obtains air direct from the atmosphere at the surface of the water, or from the air supply enclosed within its case.

If driven from its case it will soon construct another, provided suitable materials be at hand, and this work is performed with far more despatch than by caddis larvæ, the complete case seldom occupying more than a quarter of an hour.

Another species—*Paraponyx stratiotata*—feeds on the Water Soldier and other aquatic plants, and builds a case by binding leaves together with silk. But this larva differs from the last in that it breathes by branchiæ or gills until fully grown. Water passes into its case, completely filling the space between it and the insect. The latter, too, becomes wetted, having no hairs or prominences on its body to resist the water film. Its respiratory organs consist of a number of little bunches of filaments over the whole of the body, each filament containing a branch of the tracheal system; and the larva promotes a circulation of water through its case for respiratory purposes in the same manner as does the caddis larva; that is, by an undulatory movement of its abdomen.

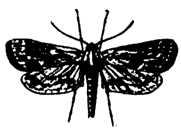

Fig. 256.—*Paraponyx stratiotata*

It will be remembered, too, that caddis larvæ have the front segments of the body protected by a hard and horny covering, so that they are safe against the attacks of at least some of their foes while crawling and feeding; and we find a similar protection in the case of aquatic caterpillars, for in these the segment next to the head is covered with a horny plate, and the head is capable of retraction within this segment.

The larva of *P. stratiotata* is not fully grown when the winter sets in, but it spends the cold season in a state of inactivity, remaining concealed within its case till the April of the following year. It then feeds again, grows rapidly, and pupates in May.

The pupa remains submerged, but the cocoon in which it changed is full of air, and the spiracles, which were functionless during the larval condition, now perform the work previously accomplished by the brachial filaments.

The perfect insect may be seen on the wing from June to August. It is larger than the last species. The forewings are yellowish brown, with lighter and darker markings, and the hind wings are white. The nature of the markings need not be described, since they are carefully depicted in the illustration. The moth may often be seen running on the surface of the water; and the female lays her eggs on floating objects.

A third species, *Hydrocampa nymphæata* (Plate V, fig. 5), is very common in our ponds, and is popularly known as the Brown China Mark. The moth varies from an inch to an inch and a quarter across. The wings are marked with white and various shades of brown, the details of which are shown in the coloured illustration. It may be seen on the wing during June and July, and lays its eggs on the under sides of the floating leaves of pond-weeds (*Potamogeton*) and Water Lilies.

The caterpillar feeds on these plants, burrowing into the leaves while very young and small, but living in cases of its own construction after it has become too large to find a home between the epidermal layers of the leaves.

The manner in which it constructs its case is very interesting. It first cuts out a circular or oval piece of a leaf, the piece being longer than its own body. It then applies this to a second leaf, placing the concave sides in apposition, and binds the two together by means of the silk from its salivary glands. Sometimes it will remain fixed to the plant in this way until it is obliged to travel for further supplies of food, but sooner or later it secures its freedom by biting away the side of its case.

At first the case is full of water, and the caterpillar derives its air from the water, but it has no gills, and the manner in which it breathes does not seem quite clear. Later in life, however, it constructs a case that resists the water, leaving an opening only just large enough to allow its foremost segments to protrude, and this aperture closes owing to the elasticity of the substance of which the case is constructed when the caterpillar retires.

It hibernates during the winter, and is fully grown in May, at which time it is about an inch in length.

When about to pupate it creeps up the stem of a semi-aquatic plant, where it fixes its case and spins a silken cocoon within it.

We have two other aquatic moths, one being the Beautiful China

Mark (*Hydrocampa stagnata*) (Plate V, fig. 6), and the other called *Acentropus niveus*. The life histories of these insects are very similar to those of the preceding species. The larva of the former feeds on the pith and leaves of the Bur Reed, and that of the latter on the pondweed *Potamogeton pectinatus*. Both hibernate during the winter, and pupate in May or June; and the perfect insects fly during June, July, and August.

Aquatic Coleoptera

Most people probably think that they are competent to distinguish between beetles and other insects, and yet the fact that a certain insect pest—the Common Cockroach—that belongs to the *Orthoptera* or Straight-winged Insects is generally known as the 'Black Beetle' is ample proof to the contrary.

The chief character of the *Coleoptera* is that denoted by the name of the order, a word which signifies 'horny-winged'; for the outer wings of a beetle are of a hard and horny character, and not parchment-like, as is usual with orthopterous insects. These hard outer wings (*elytra*) are not adapted for flying, but are merely protective, and form a complete covering for the second membranous pair, which are folded up beneath them, and are usually organs of flight.

Beetles are to be found more or less in nearly every locality—on land, under the ground, in caves, feasting in the interior of decomposing organic matter, in our provision stores, on the sea-shore, and, what is most important to us at the present moment, in almost every pond, ditch, and stream.

Some are 'water-lovers' only in the sense that they occasionally take a dive, but others spend nearly the whole of their existence on or beneath the surface.

The number of aquatic beetles is very large, and it would be impossible to give even a very short account of every one. So I shall select a few typical examples, and deal with them as fully as our space will permit.

The aquatic *Coleoptera* belong principally to three families—the *Dytiscidæ*, *Gyrinidæ*, and the *Hydrophilidæ*; and as some of the species in different families are often very much alike in general appearance, it will be necessary at the outset to learn how to distinguish between them. So, before describing individual species, we must note the characteristic features of the groups.

In the first place, then, it must be observed that the *Dytiscidæ* are more especially the predaceous family of water beetles, a fact which is suggested by the comparatively large and powerful mandibles. Their antennæ, too, are long and slender, and composed of many joints; and their hind legs, which are long and fringed with stiff hairs, are used after the manner of oars.

FIG. 257. — ANTENNA OF *Dyticus marginalis*, ENLARGED

The *Gyrinidæ* are commonly known as the Whirligig Beetles, and both the popular and the scientific names of the family have been given on account of the active gyrations or whirling movements of the insects as they paddle about on the surface of the water. This family may be readily distinguished by the nature of the antennæ, which are short and thickened; and by the fact that the hind legs are short and broad, while the front legs, which are short in the *Dytiscidæ*, are comparatively long.

Those of the third family—*Hydrophilidæ*—are not so voracious as the *Dytiscidæ*, but subsist more or less on a vegetable diet; hence we find that their mandibles are comparatively small. In the form of the legs they somewhat resemble the *Dytiscidæ*, but they may be readily distinguished from the members of this latter family by the antennæ, which are clubbed or knobbed at the extremity, and consist of fewer joints.

The character of the antennæ may be seen at once by reference to accompanying illustrations of the antennæ of species from the

FIG. 258.—ANTENNA OF *Gyrinus natator*, ENLARGED

FIG. 259.—ANTENNA OF *Hydrophilus piceus* (MALE), ENLARGED

typical genus of each family, and other important marks of distinction will be illustrated when we come to the descriptions of the types chosen.

No one could look at a typical water beetle without noticing at once its adaptability for aquatic life. Its body tapers more or less at both anterior and posterior ends, so that but little resistance is offered to it as it moves through the water. The same purpose is also served by the smooth and polished surface of the elytra and, in fact, of all parts of the hard external covering of the body. Some of its limbs are flattened and oarlike, and furnished with a row of stiff bristles which can be made to stand out in the form of a fringe, or to fall against the surface of the limb in such a manner as to be hardly discernible. Thus the beetle, when swimming, can widen the blade of its oar when propelling its body through the water, and reduce the resistance offered to a minimum during the 'back-stroke,' a feat that is accomplished by an oarsman by the movement which he terms the 'feathering of the oar.'

Again, the forelegs, which are used almost entirely as organs of prehension, either for seizing the prey or to anchor the body to pondweeds or other submerged objects, are peculiarly adapted to their work by being clawed and not unnecessarily long; while the other legs, and especially the third pair which constitute the principal means of locomotion, are long and powerful, with the above-mentioned fringe well developed, and the claws, unnecessary in this instance, in a more or less rudimentary condition. Also, the hindmost pair of limbs, which are the chief, if not the only ones used in swimming, are joined to the body much further behind than in the land beetles, which require all three pairs for walking and running.

There is yet another important difference between the land and the water beetles; for while in the former all the limbs are jointed to the thorax in such a manner that they can be moved vertically as well as horizontally, thus enabling the insect to raise its body off the ground as well as to push it onward, the swimming limbs of the latter are capable of the horizontal or propelling movement only. The vertical movement would of course be useless to a creature that requires its legs only while submerged in water, and the peculiar nature of the joint which thus restricts the movement of the swimming limbs to one plane undoubtedly adds to their power as organs of propulsion in water.

Water beetles are further gifted with considerable powers of flight, though most of them are unable to start on the wing unless they first obtain a foothold on the bank, on a floating object, or on the exposed portion of an aquatic plant. They usually fly at dusk, or during the dark hours of the night, and migrate over considerable distances in search of suitable ponds in which to obtain their food or to deposit their eggs.

In many cases they terminate their flight in a very peculiar and abrupt manner. Finding themselves over the surface of a piece of water, they suddenly close their wings and simply allow themselves to fall into it. It is probable that in this matter they are enabled to judge of their position with regard to the water by the sense of sight only; hence it is easy to understand that they may often be deceived by reflections from bright surfaces other than those of ponds and streams. It has often been observed that water beetles, thus deluded, have allowed themselves to fall on the glass roof of a greenhouse. On one occasion, too, I myself observed a large one drop directly on a garden path over which a pail of water had just been thrown.

We must now leave these general matters and proceed to examine a few of our aquatic beetles in detail.

Dyticus marginalis

(Plate III)

We cannot do better than take *Dyticus marginalis* as our type of the family *Dytiscidæ*; for not only is it a fine, powerful insect, of such a size that the beginner can easily make out its general structure, but it is also so common and so widely distributed that it is sure to turn up in the young collector's net during the earliest portion of his pond-hunting career.

It is a very easy matter to determine whether *Dyticus*[1] is at home without making any use of the net. Simply approach a pond very slowly and cautiously, and scan the surface of the water. If this insect is present you will probably see it resting at the top, with its body turned obliquely downward and the tip of its abdomen just above the surface. Or, if it is not visible, remain perfectly still for a minute or two, and if the species is present in the pond at all, it will soon come to the surface to renew its supply of air, and either rest there for a time, or immediately dart below again for an interval. Whether you see it or not, make a few sudden dashes with the net among the weeds near the banks, thrusting it towards the bottom of the water and then sweeping it upwards.

[1] This name is often wrongly spelt *Dytiscus*.

In this manner you may secure Dyticus in nearly every weedy pond, even down to the tiniest puddle, only a foot or two in width, or in ditches so narrow that there is barely room to play the net.

Although the beetle is a large and powerful one, more than an inch in length, you need not hesitate about taking it into your hand. It never attempts to use its powerful mandibles on such occasions, though it may possibly prick your finger slightly with spiny projections on the under surface of its body. The spines referred to project backwards from the metasternum—a hard plate that forms a shield under the hinder part of the thorax—just at the bases of the hind limbs. Similar spines are to be seen on others of the *Dytiscidæ*, but they vary in form in different species.

FIG. 260.—UNDER SIDE OF THE BODY OF *Dyticus marginalis*, ENLARGED

When placed on the ground its movements are exceedingly awkward. It cannot even *drag* its body along with anything like a steady movement, but jerks itself about in a fitful manner and in all directions by throwing back its long hind legs. And if it is placed on its back on a smooth level surface it has but little power of righting itself, and spins round and round in a most ludicrous fashion in its vain endeavours to find a foothold.

The upper surface of this beetle is of a very deep brown colour. The thorax has a continuous yellowish margin all round, and the elytra have a similar border on the outer side. The eyes are large and very prominent, and are so situated that the insect is enabled to look both upward and downward at the same time.

The under side is much lighter in colour, being principally of the same yellow tint as the margins above.

There is a considerable difference between the male and female *Marginalis*. The elytra of the former (Plate III, fig. 3) are smooth and polished, and their surface is not varied in any way except by three rows of very small punctures which are scarcely noticeable. The elytra of the female (Plate III, fig. 3A), however, are deeply grooved from the base to beyond the middle.

A still more interesting difference may be seen in the front legs, the first three segments of the tarsi of the male being considerably dilated, so that they form a plate-like disc. This disc is really an important organ of prehension, used principally by the male for seizing and clinging to its mate; and its structure is particularly interesting, and should be examined by every one who has a microscope.

FIG. 261.—FORELEG OF THE MALE *Dyticus marginalis*, ENLARGED

On the under surface there are a large number of circular suckers, the majority of which are very small, but two are considerably larger. The smaller ones are stalked, so that they are brought out on a level with the larger ones, and thus the whole may be applied to a smooth surface to which the insect desires to cling.

It was thought that these suckers were of a pneumatic character, their adhesiveness being due to air pressure; but there seems to be no doubt that the power of their grasp is due to the secretion of a sticky fluid.

The two distinguishing features just mentioned will enable one to distinguish the sexes at once; but it should be known that the surface of the elytra is not in itself an infallible mark, for occasionally we meet with males that are furrowed, and females that are almost, if not quite, as smooth as the majority of the males.

In order to study the habits of this insect we must transfer it from our collecting box to an aquarium where it may be kept under close observation; but, remembering its carnivorous nature, we must be careful not to allow it to associate with other creatures to which we attach any value. It seldom attacks its own species (though it never hesitates to devour a dead companion), and it does not as a rule kill water beetles of other species. Sometimes, however, it will attack these, and its jaws are sufficiently strong to penetrate their horny elytra.

Soft-bodied creatures are eagerly devoured, and it is not slow to prey on its own larvæ. It will even seize fishes as they swim, and mercilessly devour them as they struggle hard to shake off their foe. Even molluscs are not proof against their ravages, for the voracious *Dytici* will bite through their shells to feed on the soft body within.

Further, they are not in any way particular concerning the freshness of the food they devour, but are equally fond of decomposing flesh, and will feast greedily on the carcase of a creature that has been dead for a considerable time. In captivity they may be fed on flesh of any kind, and may therefore be made to partake of fragments of our own animal food.

Fig. 262.—Tarsus of Male *Dyticus*, magnified

There is one thing, however, in which the keeper of these carnivorous beetles must be careful, and that is, to see that the aquarium is not allowed to contain fragments of animal food over and above that really required to satisfy their voracious appetites; for such fragments, if allowed to remain in the vessel, will decompose and render the water most offensive and dangerous. Such a condition is generally indicated by the turbid appearance as well as by the unpleasant odour of the water; and as soon as these signs are noticeable the water should be changed at once, and the superabundance of dead matter removed.

In transferring the beetles from the collecting box to the aquarium we generally observe that they emit a fluid of a very unpleasant odour; and should this fluid touch the fingers it will be found that the objectionable smell is somewhat persistent, for it can be detected even after the hands have been well washed.

The fluid referred to is of a milky appearance, and exudes from the front part of the thorax; and the odour will probably recall that of sulphuretted hydrogen gas to one who is acquainted with the latter. In addition to this, the anal glands at the tip of the abdomen also discharge a yellowish liquid that partakes of the odour of ammonia.

Most carnivorous animals have their equally carnivorous foes, and it is possible that even the sturdy and hard-bodied *Dyticus* is occasionally attacked by larger and stronger creatures; but it is highly probable that the fluids ejected from its body constitute a valuable means of defence, and we can easily imagine that its body would be hastily ejected from the mouth of its captor as soon as the odour and perhaps also the taste of these fluids were realised.

As we watch the *Dyticus* in the aquarium we observe that its body is considerably lighter than its own bulk of water, for the insect cannot remain below without a foothold. Also, as it swims, we find the body has a tendency to take an oblique position in the water, the abdomen being higher than the head. This is best observed when the insect releases its hold at the bottom and simply allows its body to rise to the surface. At such times it rises tail foremost, the tip of the abdomen first penetrating the surface film, thus showing that this portion of the body is lighter than the fore-quarters.

When it reaches the surface it generally remains there for a time, raises its elytra a little from the body, and exposes a space that contains air, thus leading us to suppose that the position taken has some connection with the process of respiration.

And such is actually the case, for the space between the elytra and the body is an air cavity, on the floor of which are the stigmata or openings which communicate with the system of breathing tubes. And thus, while the insect rests at the top of the water, it is enjoying the advantage of a free communication with the pure air above, and at the same time keeping a watch below for any poor victim that may happen to pass within its range. If now it is alarmed at the approach of an enemy above, it immediately darts downward, taking with it a supply of fresh air under the horny wings, and often exposing a large silvery bubble at the extremity.

Dyticus marginalis may be found in ponds more or less all the year round. Even in the depth of winter, except when the weather is severe, it is resting and feeding among the weeds. Unlike the majority of insects, it often survives more than one winter. It would be impossible to ascertain its longevity in a free state, but it is very common for the perfect insect to live over two years in a state of captivity. I have at the present time three healthy specimens remaining from a 'take' of about a dozen, that are now entering their third summer.

The process of egg-laying may be watched in captivity, provided the insects have plenty of room and the aquarium in which they are kept is well supplied with weeds. The female makes a number of incisions in submerged stems by means of the sharp blades of her protrusile ovipositor, and deposits one or more eggs in each. This is generally done during early spring, and the young larvæ escape from the eggs in the course of a few weeks, the time varying with the forwardness of the season.

The larvæ are very predaceous, though not active, and secure their prey by stealth. They are of a dull yellowish or brownish colour, hardly distinguishable from the mud on which they often lie in ambush.

FIG. 263.—LARVA OF *Dyticus marginalis*

The body is elongated, tapering at the tail, which terminates in a pair of fringed appendages. The head is joined to the thorax by a narrow neck, and all the segments of the body are distinctly marked. The head is large and rounded, and furnished with a pair of long and slender sickle-shaped jaws, and six small eyes (ocelli) on each side. The six legs also are long and slender, terminating in a double claw. They are well adapted for crawling over the mud and among pondweeds, and, being fringed with hairs throughout their length, are useful as swimming organs.

If we watch the larva as it moves about in the aquarium, we observe that its body is lighter than water, so that it cannot remain below unless it is anchored to submerged objects by means of its hooked claws. The tip of the abdomen also is generally curved upward.

When the creature wishes to breathe, it releases its hold and allows its body to rise, still keeping the tail curved upward. On reaching the top (Plate III, fig. 3c) the tail is thrust through the surface film, and emerges into the air perfectly dry. Then, since the fringed appendages are not easily wetted, they serve to buoy up the abdomen, while the forepart of the body is supported by the legs.

Air is then absorbed from the atmosphere into two tracheal trunks—one in each appendage; and these trunks are continuous with the two main air-vessels that run longitudinally throughout the length of the body, and which give off branching tracheæ to each of the segments.

In this position the larva is perpetually on the look-out for unwary victims that may come within its range, and such are seized by a sudden pouncing movement of the body, and the equally sudden clasping of the sharp mandibles, which close within the body of its prey, thus rendering all struggles useless.

Now the captor takes up a position of rest, and immediately commences its meal; but no movement is to be observed in connection with its feeding, for it does not masticate its food, but simply extracts the juices of its victim by suction through its jaws.

Its mouth is very rudimentary, being represented by a mere horizontal slit between the broad labrum and labium; and these two parts being generally locked together, this slit is not readily observed.

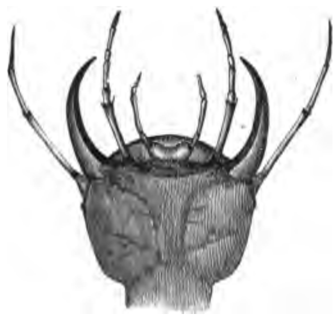

FIG. 264.—UNDER SIDE OF THE HEAD OF *D. marginalis* LARVA, ENLARGED

If we examine the mandibles, however, we find that they are grooved on the inner side, and that the groove is covered by a membrane and thus converted into a tube, which is open at the apex and at the base of the jaw. It is through this tube that the larva sucks the juices of its prey, the power of suction being supplied by a portion of the alimentary tube that is capable of being enlarged by the contraction of certain muscles. These muscles connect the walls of the cavity with the chitinous covering of the head, and by their action convert the cavity in question into a kind of suction pump. So effectual indeed is this apparatus, that the body of the victim is drained till little is left but a transparent framework that still retains the form of the original animal.

The larva grows very fast, and undergoes a series of moults or changes of skin. It is fully grown in less than two months, and then creeps out of the pond and buries itself in the soil in the immediate neighbourhood of the water. It must of necessity leave the water in order to undergo this change, for the pupa being quiescent it could not rise to the surface at intervals in order to renew the supply of air.

If the change is completed before the autumn sets in, the perfect insect emerges in a week or two; but if pupation does not take place until the season is well advanced, the insect hibernates in its pupal condition, and emerges as soon as the sun of the following spring is sufficiently powerful to call it forth.

When freshly emerged the perfect insect is pale in colour, and its outer covering is soft and flexible, but it assumes the normal appearance in the course of a day or two.

The other species of the genus *Dyticus* are so much like *Marginalis* in general structure and habits, that the description just given of the latter applies almost equally well to all, and in fact also to the other genera of the same family. And as the family includes over a hundred members and about eighteen genera, it will be impossible to give the reader even a fair collection of types. We will, however, figure a few other water beetles belonging either to the same or an allied family.

The first of these is *Hydroporus* (*Deronectes*) *duodecim-pustulatus* (12-*pustulatus*), which represents a genus of small beetles,

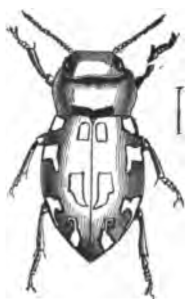

FIG. 265.—*Hydroporus* 12-*pustulatus*, ENLARGED

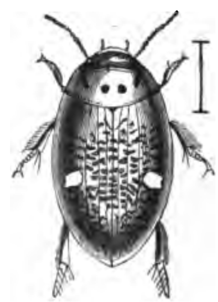

FIG. 266.—*Agabus biguttatus*, ENLARGED

of which the present species, though only about a quarter of an inch in length, is one of the largest. They are also flatter than the typical genus. The elytra are black, and marked, as shown in the illustration, with six reddish-brown spots on each side—a feature which has given rise to the specific name. This little beetle is very common in some localities. Another species (*Acilius sulcatus*) is shown on Plate III (fig. 4).

The next example—*Agabus biguttatus*—represents a rather large genus of about twenty species, most of which are to be found in running water. The thorax and abdomen are yellow, the former with two small black spots at the middle, and the latter with a

FIG. 267.—*Pelobius Hermanni*, ENLARGED

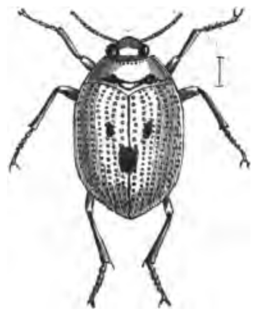

FIG. 268.—*Cnemidotus impressus*, ENLARGED

larger bright yellow spot on each side. The elytra are also marked with small dark brown dashes. This species inhabits running water.

It will be observed that *Hydroporus 12-pustulatus* does not appear to be so well adapted for aquatic life as *Dyticus marginalis*. In fact it looks more like a terrestrial than an aquatic beetle; and the same remark applies to two of the remaining three species figured, all of which are sometimes placed outside the *Dytiscidæ* family. They are small beetles, two of them being only about a sixth of an inch in length; hence the figures are enlarged in order to show more plainly the details of their markings. The largest of the three (*Pelobius Hermanni*) is peculiar on account of the strange rasping noise it makes when irritated. This it does by rubbing the rough edge of the last segment of the abdomen against the elytra.

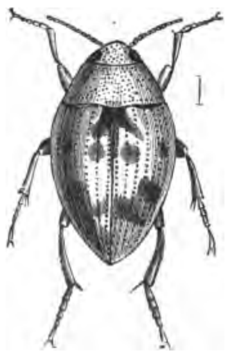

FIG. 269.—*Haliplus variegatus*, ENLARGED

WHIRLIGIG BEETLES (*Gyrinidæ*)

I have already pointed out one or two important features by which the *Dytiscidæ* may be distinguished from the *Gyrinidæ*, and now we will take a well-known type of the latter family for examination.

One of the first things to attract our attention as we look on a pond or stream is often a group of little oval creatures, with highly polished bluish-black bodies that glisten in the sun like burnished metal, sporting about with rapid gyratory movements on the surface.

These are commonly called Whirligigs, or, more correctly, *Gyrinidæ*, both these names being suggested by their characteristic whirling motions.

They are decidedly gregarious in their habits—at least, the commonest species, *Gyrinus natator*, which we choose as our typical example, is.

You wish to catch a few of these creatures, and so you make a sharp dash with the pond net, of course not striking downwards, but making a rapid horizontal stroke with the ring of the net half submerged.

FIG. 270.—*Gyrinus natator*, ENLARGED

As soon as the stroke is over, not one is to be seen on the spot where the little group were sporting together, so you naturally conclude that you have cleverly netted them all. But on looking into the net you find you are quite mistaken. Most of the little beetles have made a sudden dive to the bottom, performing the movement with such rapidity that they escaped the snare.

Then you stand motionless for a time, watching the surface, and one by one the lively insects reappear as suddenly as they darted out of sight; and before many minutes the little company have assembled in the same little spot to resume their circular dance.

These beetles are very interesting in the aquarium, but they should have plenty of room for their sports on the surface of the water. There is, however, some little difficulty in keeping them supplied with their natural food, which consists of various small insects. In the outdoor pond or stream they probably subsist largely on insects that accidentally fall into the water; but food from this source would be at a minimum in an indoor aquarium, and therefore it becomes necessary to introduce food for them.

It should be remembered, too, that they can fly well, provided they can get a foothold, and consequently it is necessary to cover the aquarium containing *Gyrinus* with gauze if their aërial excursions are to be prevented. Even if there are no floating objects on which they can rest while they unfold their wings, they seldom have much difficulty in creeping up the sides of the vessel in which they are placed, though the surface may be smooth and clean, the slight adhesiveness of the water being sufficient to allow them to push themselves up by the aid of their hind legs.

These legs are very broad, and fringed with stiff hairs, so that they form admirable paddles for locomotion on the surface as well as below. The forelegs are longer, and are used both for seizing the prey and for prehensile purposes generally.

The body of *Gyrinus* being lighter than its own bulk of water, the insect has to exert itself in order to dive below, and is obliged to anchor itself when it desires to remain submerged. It breathes much in the same manner as *Dyticus*, having an air space between the elytra and the upper surface of the abdomen; and as it swims beneath the surface the bubble of air that always remains exposed at the tip of the body looks like a little ball of polished silver.

It will be seen from fig. 258 that the form of the antenna is very peculiar, having the appearance of a double appendage. This is due to the fact that the third joint is very large, and extends laterally beyond the others before and behind it. Perhaps, however, the most remarkable feature of the head is the form of the eyes. These organs are double, each one being divided into upper and lower parts that are quite distinct from each other. It is probable that this arrangement enables the insect to see objects distinctly both above and below it at the same time; and it has also been said that the lower half of each eye is submerged as the beetle sports on the surface of the water. If this is the case, the insect would be able to see objects in the water much more clearly than if its eyes were elevated, for the vision would not be disturbed by the fitful reflections of the water thrown up into ripples by its rapid movement.

Gyrinus lays its eggs early in the summer on the submerged stems of aquatic plants, and the larvæ are hatched in from one to two weeks.

The larva is purely aquatic, and may be found in plenty throughout the summer in most ponds, and also in the sheltered nooks of streams. It has somewhat the appearance of a centipede at first sight, but when closely examined it will be found that only three of its prominent appendages are true legs, the others being fringed breathing organs, each one of which contains a breathing tube that communicates with the air system of the body.

The legs are of course attached to the first three segments next the head. All the remaining segments are furnished with breathing appendages, each of the first eight having one pair, and the last one two pairs.

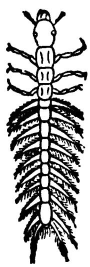

FIG. 271.—LARVA OF *Gyrinus*, ENLARGED

The larva is predaceous, feeding on various aquatic creatures, but is not nearly as voracious as the larva of *Dyticus*. In fact, it has been asserted that it will take to a vegetable diet at times, either out of mere choice, or perhaps only when the supply of animal food is insufficient to satisfy its requirements.

When fully grown it leaves the water and creeps up the stem of an aquatic plant. Here, or rather on the leaf, it constructs an oval silken cocoon, within which it changes to a quiescent pupa.

The perfect insect usually emerges towards the end of the summer, at which time *Gyrinus* may be seen in abundance almost everywhere. When the chilly weather sets in, numbers of them die off, but many protect themselves from the cold by burrowing into the mud, where they remain in a dormant or semi-dormant condition.

A long stretch of mild weather, even in the middle of winter, will call them out from their hiding places; and very early in the spring they may be found in groups on the surface, the numbers being great after a mild winter.

There are eight British species of the genus *Gyrinus*. The one described is only a quarter of an inch in length, but another—*G. bicolor*—which is found principally in brackish water, is considerably larger.

One species, known as the Hairy Whirligig (*Orectochilus villosus*), has its elytra covered with a fine short hair. This species is very common in some of the rapid rivulets of Devon, and I have taken many from the two streams which unite to form the river Plym; but they do not seem to be abundant in many localities. This insect does not play in the bright sun, as does *Gyrinus*, but may be seen at dusk.

Hydrophilus piceus

Our type of the family *Hydrophilidæ* is the fine insect popularly known as the Silver Beetle, and whose scientific name is *Hydrophilus piceus*.

The popular name does not convey any idea of the actual colour of the insect, for its body is of a very dark olive-green above and black below. But a large area of the under surface is covered with

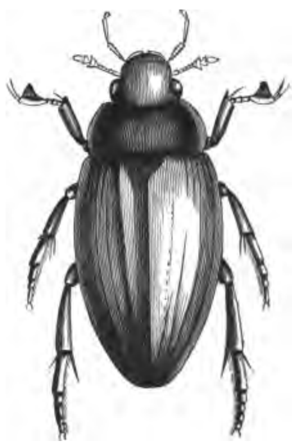

FIG. 272.—*Hydrophilus piceus*, MALE

FIG. 273.—*Hydrophilus piceus*, MALE, UNDER SIDE

a short and thick yellowish downy hair which resists the water, and the layer of air that remains permanently entangled between this down looks just like a breastplate of bright silver if viewed in certain lights when the insect is submerged.

This splendid beetle is the largest of our Coleoptera with the exception of the Stag Beetle, and even this is but little superior in point of size. And being almost perfectly harmless, it has naturally become a great favourite with keepers of aquaria, who have searched far and wide for it in ponds and ditches; and thus its numbers have been greatly reduced, while the destructive *Dyticus marginalis*, generally neglected by the aquarium keeper, continues to show itself almost everywhere in abundance.

The principal characters by which we are enabled to distinguish between the *Hydrophilidæ* and the other two families of aquatic beetles already considered are the short mandibles, the short and clubbed antennæ, and the comparatively long palpi which, in the case of *H. piceus*, are longer than the antennæ.

On account of its superior size, *H. piceus* is not likely to be confused with any of the *Dytiscidæ* except *D. marginalis*, the largest species of the family; but the features mentioned above, as well as the description which follows, will make the distinction between the two insects perfectly clear, even to the most casual observer.

It is usually more than an inch and a half in length, and about three-quarters of an inch across the middle of the abdomen. The thick yellowish-brown downy hair already referred to covers the whole of the thorax and also the margins of the abdomen on the under side.

The metasternum terminates behind in a sharp projection that is directed backward—not two short and wide spines as in the case of *D. marginalis*, but a single narrow and very sharp spine, more like the point of a large needle; and as this spine is raised considerably off the general surface of the body, it is very liable to penetrate the skin of one who carelessly handles the insect, though the creature itself does not seem to know how to make use of it as a weapon of defence.

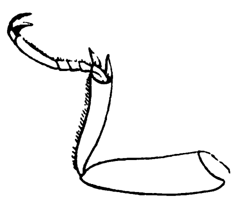

FIG. 274. — FORELEG OF *Hydrophilus piceus*, FEMALE

The forelegs are short, and terminate in two rather large claws; and are used by the insect as it creeps among the pondweeds, as well as for prehensile purposes generally. The tarsus is dilated in the male, forming a large triangular plate, and this feature serves as a ready means of distinguishing between the sexes. The second and third legs are long, especially the latter; and both these are used as oars when the beetle swims. And here, again, we must note an interesting difference between the present species and *D. marginalis*—this time a difference in habits; for while the latter insect moves its 'oars' simultaneously, *H. piceus* works its swimming legs alternately, and is consequently not nearly so steady a swimmer as the other. It is also far less active, and seems to prefer creeping to swimming.

The wings are very large and powerful, and the thin membrane of which they are composed is supported by a few very strong nervures.

It is probable that the long palpi are commonly mistaken for the antennæ; for not only do they resemble the antennæ of many other beetles, but they are always well displayed, and even, it is

FIG. 275.—*Hydrophilus piceus*, WITH WINGS EXTENDED

supposed, perform the functions of antennæ generally, being highly sensitive. Then, again, the real antennæ are closely concealed below the projecting rim of the covering of the front segment of the thorax, in which position they are of service in assisting the process of respiration.

Let us watch *H. piceus* in the aquarium, to see how this process is carried on. It rests at the bottom among some weeds, holding on by means of its legs. After a minute or two it becomes restless and makes one or two creeping movements among the vegetation Then it clambers among the tangled weeds till its body is free, and swims upward till it reaches the surface. Here it takes up an inclined position with its head uppermost, and turns its body a little on one side.

If we now look up at the under surface of the beetle we see the silvery layer of air that covers the hairy portion of the integument. It includes the whole under surface of the thorax, a transverse band across the front portion of the abdomen, and the lateral margins of the abdomen reaching to the tip. A lens will also reveal the fact that the clubbed extremity of the antenna is covered with down, and, like the surfaces just mentioned, cannot be wetted by water. Thus this portion of the antenna is always surrounded by an air film; and, lying as it does under the projecting edge of the front segment of the thorax, its air film is continuous with that which covers the whole downy surface, and this, again, is continuous at the margins of the elytra with an air space between the elytra and the upper surface of the abdomen.

Now, if we watch the insect closely as it rests at the surface of the water, we find that it has brought the air film between the thorax and the antenna on one side of the body into direct communication with the outer air, and it is to attain this object that the creature turns its body slightly on one side. Thus the whole layer of air beneath the body is now connected with the atmosphere above.

Further, as we watch the insect from beneath, we see the elytra moving up and down, thus causing the air film to alternately swell out and become thinner again. At the same time the whole body of the beetle rises and falls with a gentle swinging motion corresponding with that of the elytra.

Thus we get an insight into the interesting manner in which to insect breathes. The action of the elytra reminds us of the action of a pair of bellows. By their movement the air space beneath them is alternately compressed and enlarged. Each time the space is compressed, air is driven beyond the margins to the film beneath, and thence to the point of communication with the atmosphere just inside the antenna of the higher side of the body, and at this point we can see the union between the submerged and outer air distinctly by looking down on the water from above. The air thus expelled carries with it the carbonic acid gas given off as a product of respiration; and the specific gravity of the body being thus increased, it falls a little in the water.

Immediately on this movement the elytra are raised again, thus enlarging the air space over the body, and fresh air rushes in along the same path to fill it up; and the specific gravity of the body being again reduced, it rises.

After these movements have been repeated a few times, the beetle swims below, carrying with it an abundant supply of fresh air. So great is this supply, indeed, that the insect has to exert itself considerably in order to reach the bottom; and it often has to part with a portion by compressing the air space beneath the elytra in order to reduce the labour of the descent.

I should like to say much more concerning the interesting and instructive habits of this beautiful aquarium pet, but must pass on to a brief account of its metamorphoses. The reader, however, is strongly recommended to hunt for it, and so be in a position to investigate for himself. Use the net freely among the weeds of stagnant water, dipping deeply and striking upwards; and if all efforts are in vain as far as *H. piceus* is concerned, procure a few specimens from a dealer in aquarium pets rather than remain personally ignorant of our finest British water beetle. Remember that pond vegetation constitutes its principal food as well as its natural home, and give it a very liberal supply.

The female is provided with a spinning apparatus which, like that of the spider, is situated at the tip of the abdomen. By means of this she spins a cocoon at the surface of the water, mooring it to the stem or leaf of an aquatic plant. The cocoon is rounded, but flattened on one side. Before it is finally closed she fills it with air from her own personal supply, and then deposits within it from fifty to a hundred white eggs. Her abdomen is next withdrawn and the opening quite closed up; and she completes her task by spinning a conical projection, half an inch or more in length, the purpose of which does not seem quite clear.

The cocoon, soft at first, soon becomes hard; and being watertight, the eggs, and the young larvæ when hatched, are dry and well supplied with air.

Fig. 276.—Larva of *Hydrophilus piceus*

Shortly after the larvæ have escaped from their prisons, they find their way out of the cocoon and swim away into the water below.

The larva is a soft-bodied grub of a dull greyish colour, tapering off considerably towards the tail, and also slightly towards the head. The latter is black and shining, and the three pairs of legs are short in proportion to the size of the body.

It is a predaceous creature, as may be surmised from the nature of its large curved jaws, and feeds on molluscs and other inhabitants of ponds.

Like the perfect insect, it breathes the atmospheric air direct, coming to the surface at intervals for the purpose of renewing its supply. The exchange of air is carried on through the agency of the fringed appendages of the tail, which are thrust above the surface for that purpose. Each appendage contains an air tube that forms part of the tracheal system.

The larva undergoes three or four moults, and is full grown in July or early August, when it leaves the water and burrows into the soil in the neighbourhood. Here it constructs an oval cell, the walls of which are strengthened by a glutinous substance from its own body. Within this cell the pupa lies perfectly inactive till the time arrives for its emerging. All the organs of the perfect insect are now to be seen, each one encased in its own sheath; and the creature is provided with no less than eight prominent hooked appendages, three on each side of the head, and two on the tail. These support the body as it lies in the cell, and so keep it from contact with the soil. These appendages are thrown off with the cast skin when the perfect insect emerges.

FIG. 277.—PUPA OF *Hydrophilus piceus*

The family *Hydrophilidæ* contains about ninety British species, all of which resemble each other in habits and in general structure, but exhibit great diversity in the matter of size.

There are other aquatic beetles in addition to the three families *Dytiscidæ*, *Gyrinidæ*, and *Hydrophilidæ*, of which we have selected typical examples, but space can be found for only one other—a representative of the family *Parnidæ*.

This family contains fourteen British species, some of which are to be found in the water of ponds and streams, while others frequent the surface and the wet muddy banks. They are mostly very small beetles, with the head sunk deeply into the first segment of the thorax.

Our illustration represents one of this family. It is a very small insect, named *Elmis æneus*, the latter term being applied on account of the characteristic brassy colour of its surface.

The thorax is abruptly squared in the front. The elytra are marked with longitudinal rows of small punctures, and the under surface is covered with a thick short hair of a bright yellow colour.

This insect inhabits streams, even very rapid ones. It will be seen that all its legs terminate in sharp double claws, and by means of these it fastens itself securely to submerged objects, thus preventing itself from being carried away by the current.

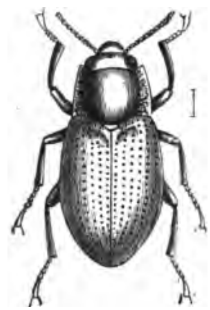

FIG. 278.—*Elmis æneus*, ENLARGED

AQUATIC HYMENOPTERA

The *Hymenoptera*, or 'Membrane-winged Insects,' form a very extensive order, and include not only Ants, Bees, and Wasps, but also large numbers of Gall Flies, Saw Flies, and Ichneumon Flies.

The general characteristic of the order is the two pairs of naked membranous wings, supported by only a few nervures. The mouth is also adapted both for chewing and for suction, the mandibles being strongly developed, and the labium and maxillæ prolonged into a sucking tube.

The abdomen is often joined to the thorax by means of a very slender threadlike waist, and the hindmost extremity of the body is furnished either with a sting or with an ovipositor.

The Hymenoptera include more than thirty thousand known species, and till about thirty years since not a single one of aquatic habits had been discovered. However, in 1863 Sir John Lubbock published an account of two minute, perfect, hymenopterous insects which he had found swimming in water, and we need hardly add that the discovery came as a great surprise to entomologists, who could hardly have expected to meet with insects possessed of such delicate wings moving uninjured beneath the surface of water.

It was evident at once that the insects in question were closely related to the group commonly known as Ichneumon Flies, which deposit their eggs on or within the bodies of other animals or, in some cases, in the cuticle of plants.

Before describing the aquatic species made known to us by the untiring observations of this eminent entomologist, it will be well to note the general habits of the Ichneumon Flies.

They are provided with long and slender ovipositors, most of which are capable of piercing the living tissues in which they lodge their eggs. The majority of them fly about among plants, carefully searching the leaves and stems for the larvæ of Lepidoptera and other insects. Each one generally shows a marked preference for some particular species, confining its searchings to the favourite food-plants of that species. Having met with a victim, it pierces the skin and thrusts one or more eggs within the body.

The larva thus wounded is apparently none the worse at first the puncture being very small, and the presence of the egg or eggs causing little or no inconvenience.

But after a short time the eggs are hatched, and the little grubs of the ichneumon fly at once commence feeding on the body of the unfortunate host, which becomes both the home and the food of its internal foes.

The larva continues to feed, and apparently to grow; but the nourishment taken builds up tissues which have only a transitory existence, for they are greedily devoured by the parasites, which grow rapidly, and thus maintain and even add to the size and general plumpness of their victim.

The ichneumon larvæ, however, generally avoid the vital organs of the body on which they feed, as though they knew that by this precaution they could maintain their supply of provisions and preserve their home; but subsist principally on the fatty matter stored beneath the skin of their host.

Thus the infected larva may live to the end of its usual term, and even successfully undergo its metamorphosis to the pupal state. But when this is the case it seldom has the strength to emerge in the perfect condition, and one or more ichneumon flies having passed completely through their changes, eat their way through the pupa, often leaving it not only lifeless, but a mere hollow shell.

Sometimes, however, the ichneumon parasites attack the vital parts of their prey, which is thus reduced to an empty skin before the transformation can take place.

Such is the life of many of the ichneumon flies, and we need not now detail the life histories of those which differ from the general rule in minor particulars.

Two aquatic species were described at the time above mentioned. One of them, named *Polynema natans*, is only one-twentyfifth of an inch in length. Its wings are quite devoid of nervures, but are surrounded by a fringe of fine hairs. It crawls over the submerged leaves and stems of aquatic plants, and even swims, with a slow and jerky motion, beneath the surface by means of its delicate fringed wings.

FIG. 279.—*Polynema natans*, ENLARGED

At first it was thought that the flies seen in the water were females engaged in searching for aquatic larvæ in which to deposit their eggs, but it was soon found the males as well as females were in the habit of making these aquatic excursions.

Another species, discovered about the same time, swims by means of its legs instead of its wings; and subsequently several others have become known through the energies of various naturalists. Some of these prey on the bodies of caddis larvæ. Others have been bred from the larvæ of water beetles; and one very small species, closely allied to *Polynema natans*, deposits its eggs within the *eggs* of dragon flies.

It is interesting to note, in conclusion, that the aquatic ichneumons are apparently but ill adapted to their peculiar mode of life. Their bodies are not pointed in such a manner as to allow of easy motion through the water. Their legs are not flattened and fringed with bristles, like those of most of the aquatic beetles and the 'boatmen.' Neither have they any special provision to allow the process of respiration to continue while their bodies are submerged. They breathe by means of stigmata like the aërial *Hymenoptera*, and therefore are not able to remain below any longer than the scanty air supply within the tracheal tubes will allow. This time, however, seems to be considerable in some species, for we are told that they can be kept below the surface for several hours together without injury.

CHAPTER XI

FISHES FOR THE AQUARIUM

HITHERTO we have been giving attention only to the invertebrate division of the animal kingdom, but now we must devote a little space to aquatic backboned animals.

The Vertebrates are usually divided into five classes—Fishes, Batrachians, Reptiles, Birds, and Mammals, the first three of which contain cold-blooded, and the others warm-blooded animals All the five classes possess water-loving creatures, but the Fishes and the Batrachians alone include animals that are structurally adapted to a purely aquatic life, the former throughout the whole of their existence, and the latter generally during their earlier stages only.

The adaptation to aquatic life to which we refer is shown not only in the general form of the body and the possession of organs for swimming, but, what is far more important, in the possession of organs by means of which air can be separated from the water in which they live. Thus the creatures in question need not come to the surface to breathe, but are enabled to derive all the air required for the aëration of the blood from the water itself.

In the present chapter we shall consider the fishes—the lowest or simplest class of the Vertebrates; and must necessarily confine our attention to a few that lend themselves most readily to the more or less artificial conditions of an indoor aquarium or of a small garden pond; and we will first note the general characters of the group or class to which they belong.

In general form they are particularly adapted for moving in water, the body being either elongated and tapering before and behind, or flattened and sharp at the edges, and in either case capable of motion in water with but little resistance.

The limbs, if present at all, are arranged in pairs, and are modified into fins for swimming; and in addition to these paired appendages there are generally other fins along the middle line, as well as the terminal tail fin, which constitutes a very powerful propeller. These, however, do not represent the true limbs of the higher vertebrates, but are outgrowths of the covering of the body.

The surface of the body is either naked, or covered with overlapping scales or hard and bony plates.

On each side of the body there is a line of scales extending from the eye to the tail, usually of a different colour from those above and below them, and each scale perforated by a small hole which leads into a little sac hat is supplied with a nerve filament. These little cavities are supposed to be organs of sense, though the exact nature of the sensa on or sensations produced by means of them has not been ascertained.

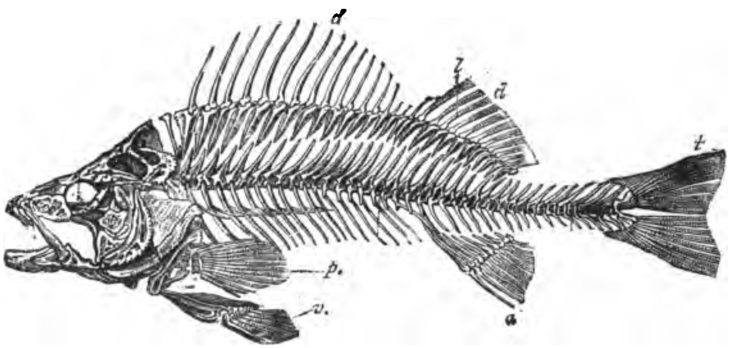

FIG. 280.—SKELETON OF A FISH (PERCH)
d, dorsal fins; *v*, ventral fin; *a*, anal fin; *p*, pectoral fin; *t*, tail fin

In some of the lowest fishes the internal skeleton is cartilaginous, but in the majority there is a well-developed bony skeleton consisting of a backbone surmounted by a skull, and giving attachment to the paired fins and the ribs.

The backbone usually consists of a chain of bony discs which are concave both before and behind. Each disc or vertebra gives rise to a bony arch above, and the summit of the arch is prolonged into a long spine. The series of arches thus formed serve to enclose and protect the great central nerve—the spinal cord—which proceeds direct from the brain, and the brain itself is enclosed and protected by certain bones of the skull.

Some of the foremost vertebræ give rise each to a pair of ribs, and these ribs form a series of bony arches on each side of the cavity that contains the internal organs. The other vertebræ have each a V-shaped bony arch below, corresponding with that above, and this series of arches affords protection to the great blood-vessel (the aorta) which supplies blood to the different parts of the body.

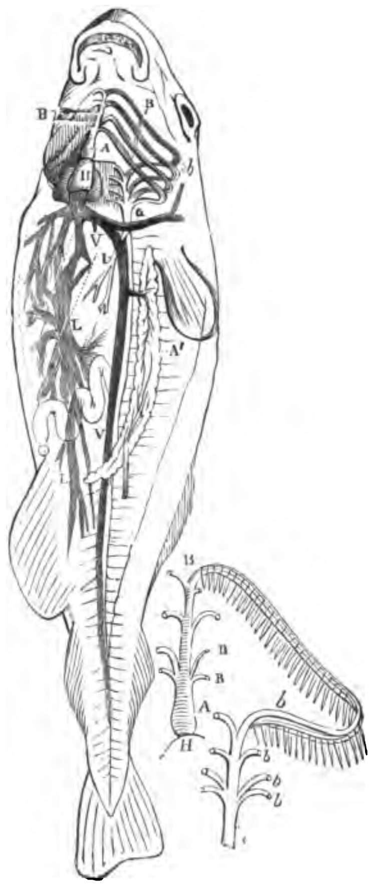

FIG. 281.—THE CIRCULATION OF BLOOD IN A FISH

A, aortic bulb; H, heart; B, arteries supplying gills; V, veins; *b*, veins conveying aërated blood from the gills to the dorsal aorta; *a*, dorsal aorta; L vessels of liver; A′, kidney

We may also note briefly the general characters of the internal organs.

The digestive tube is of very simple construction, and there is no provision for the mastication of food; for although most fishes are provided with teeth, these are usually comparatively small, and adapted only for seizing and holding their prey. The teeth are generally small and pointed, and arranged round the edges of the jaws; but in some cases they exist more or less on all the bones around the cavity of the mouth, and in others are situated only on the living membrane. They are generally renewed throughout life as fast as they become worn away.

The heart is situated just behind the head, and consists of two cavities — an auricle which receives impure blood from the veins after it has circulated through different parts of the body; and a ventricle, which receives the blood from the auricle and then propels it to the gills, where it becomes oxygenated. From the gills it flows through several parallel veins to the aorta, which sends it to all parts of the body.

The gills consist of fringed folds, richly supplied with blood, and situated either beneath moveable gill-covers or within pouches which communicate freely with the water outside. Water is being continually taken in at the mouth, and passed out again at the gill-slits just behind the head. As it passes over the gills dissolved oxygen is absorbed into the blood through the thin and soft structures that separate this fluid from the water, and at the same time carbonic acid gas that has been gathered up by the blood during its circulation in different parts of the body is given out to the water in exchange. Thus the gills of a fish perform exactly the same function as the lungs of the higher air-breathing animals; but as they are not adapted for carrying out this exchange with the atmosphere direct, fishes cannot as a rule live for any great length of time out of water.

Some fishes, however, are furnished with an accessory breathing organ, by means of which the blood is aërated by air obtained direct from the atmosphere; and in certain cases the creatures in question are so largely dependent on this source of supply that they can actually be killed by suffocation—drowned, in fact—by preventing them from reaching the surface.

Most fishes are provided with a membranous sac called the air-bladder or swimming-bladder. It lies just in front of the vertebral column in the visceral cavity, and contains air. In some cases it is quite closed, but it generally communicates with the intestine. This bladder can be compressed or dilated, and thus serves to regulate the specific gravity of the fish so that it can rise or sink in the water as it desires.

There are yet a few interesting characteristics of fishes that remain to be considered. The brain is of a very low type, and the organs of sense are of a very simple and imperfect character. The ears are simple sacs, situated in the brain cavity; and these are filled with a fluid in which float small solid stony bodies which assist in transmitting vibrations to the nerves that ramify in the walls of the sacs.

Some fishes have no tongue, and when that organ is present it is small and not capable of protrusion out of the mouth.

Finally, I must say a word concerning the colouring of fishes.

In some we find the most gorgeous tints, often exhibited in great variety in the same species; but the most interesting feature in this connection is the remarkable protective colouring of such a large number. Thus we often find the upper surface of those species which live on the bottom bearing such a close resemblance to the mud on which they rest that they are practically invisible to the numerous enemies above. Also, those species which swim at or near the surface are frequently coloured above with the same olive tints that characterise the water itself when viewed from above, and thus they are hardly visible to the fish-eating birds which hover over the water. At the same time these fishes are protected from their enemies below by the bright silvery colour of their ventral surface, which is scarcely to be distinguished from the colour of the sky by creatures beneath them.

Fishes are divided into several orders, the lowest of which includes the Pouch-gilled Fishes (*Marsipobranchii*) or Lampreys. These fishes are remarkable for the peculiar structure of their gills, which are little pouches, six or seven in number on each side, arranged in two rows. They communicate with the exterior by means of small punctures, and the blood, which circulates freely in their walls, is aërated by the absorption of oxygen from the contained water.

In general form Lampreys resemble worms rather than fishes, their bodies being long and cylindrical, and they have no paired appendages corresponding with the pectoral and ventral fins of the majority of the sub-kingdom; but they have two dorsal fins, the hindmost of which is continuous with the tail fin. They further resemble worms in that their bodies are quite devoid of scales.

They feed somewhat after the manner of leeches, having a circular suctorial mouth, by which they cling to their prey, or rather their hosts, for they attach themselves to fishes and other animals often considerably larger than themselves, and rasp away the living flesh with their small but numerous teeth.

These teeth are situated not only on the upper and lower margins of the mouth, but also on the sucking disc and on the tongue; but it is a curious fact that Lampreys undergo metamorphoses, like their nearest relatives of the invertebrate animals, the young differing from the adults not only in the absence of teeth, but also in the arrangement of fins, and the concealment of the eyes in a groove.

The River Lamprey (*Petromyzum fluviatilis*) is still to be found in some of our rivers and lakes, especially those whose beds are situated on low ground near the sea. At one time they were extremely abundant in the Thames, Severn, and several other British rivers, and were used largely as an article of diet; but now they are scarce in many of their former haunts, and are caught chiefly for bait.

This fish has been taken in the sea, and it is possible that it commonly spends a portion of its existence in salt water, ascending rivers at regular seasons in order to deposit its spawn.

We can hardly recommend the Lamprey as an ornament to the aquarium, nor can any hopes be entertained of keeping the fish alive for any length of time in a small tank; but we strongly recommend those who are unacquainted with this curious creature

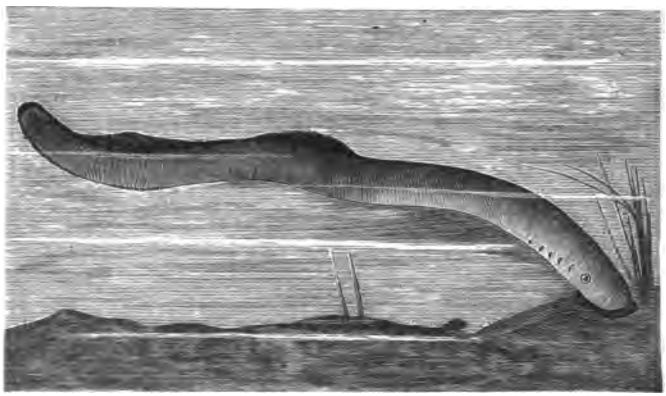

FIG. 282.—THE RIVER LAMPREY (*Petromyzum fluviatilis*)

to procure one alive, and observe its form, and its habits as far as they can be studied in confinement. It cannot fail to be interesting on account of its unfishlike nature. Like worms and leeches it has no true jaws, no ribs, and no limbs; and were it not for the rudimentary spine, which, by the way, is not a true bony structure as in most other vertebrates, we should probably class the creature with the *Vermes* division.

Passing over the Sharks and Rays, and also the Ganoid Fishes, whose bodies are covered with hard and polished plates, both of which orders are not represented in our ponds and streams, we come to the extensive order of bony fishes (*Teleostei*), or fishes whose skeletons are composed of true bone.

This order includes all our freshwater fishes with the exception of the Lamprey already mentioned. Their bodies are covered with scales, and their gills are composed of comblike fringes, supported on bony structures, and situated under gill-covers at the back of the head.

Although all the *Teleostei* resemble each other in the particular just mentioned, yet they include an enormous assemblage of fishes, exhibiting a remarkable diversity of form and habit; hence they are divided into sub-orders, which are further split up into families.

The principal sub-orders are—

1. The Tube-bladdered Fishes (*Physostomi*), distinguished by the presence of a duct which forms a means of communication between the swimming-bladder and the digestive tube (fig. 283). The

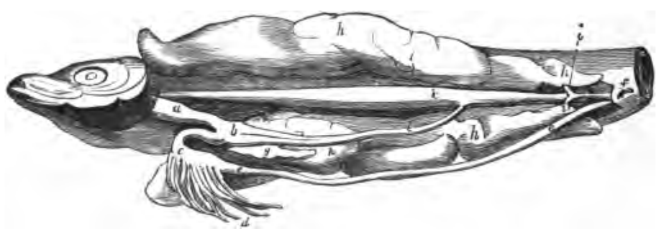

FIG. 283.—INTERNAL ORGANS OF ONE OF THE *Physostomi* (HERRING)

a, œsophagus; *b c*, stomach; *e*, intestine; *l*, duct of swimming-bladder; *k*, swimming-bladder; *h*, ovary or egg-producing organ

fin rays are also soft and flexible, and made up of several jointed parts, with the exception generally of the front ray on each fin, which is hard and spiny.

2. The Soft-finned Fishes (*Anacanthini*)—another group of soft-rayed fishes, in which even the front rays are flexible, and in which the swimming-bladder, if present at all, has no duct leading to the digestive canal.

3. The Spine-finned Fishes (*Acanthopterygii*), with hard and spiny fin rays, and in which the hind margin of the scales is serrated or spiny. These also have either no swimming-bladder, or the same has no duct.

There are other sub-orders of the *Teleostei*, also another order containing only three fishes; but these do not include any species

PLATE VI.

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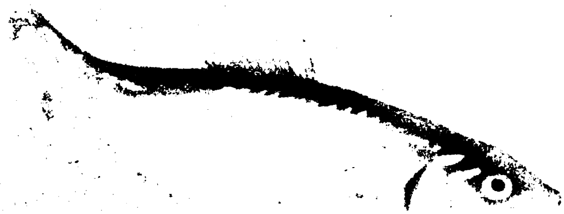

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which concern us at present. We will now proceed to note briefly some of the species to be found in our ponds and streams, and which may be studied in the aquarium.

The Tube-bladdered Fishes include Eels, Carp, Gudgeon (Plate VI, fig. 1), Barbel, Rudd, Minnow (Plate VI, fig. 2), Roach, Chub, Dace (Plate VI, fig. 3), Tench, Bream, Bleak, Loach, Pike, Salmon, Trout, Grayling, and Charr. Of course some of these are not likely

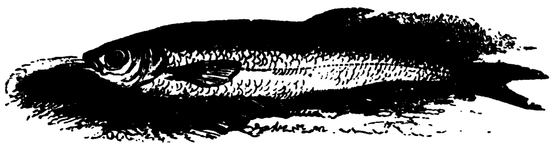


FIG. 284.—THE BLEAK (*Alburnus lucidus*)

to come in the way of any but experienced anglers, and others are not at all suitable for small aquaria; still there is no reason whatever why any small fish captured by the owner of an aquarium should not be kept, at least for a time, so that its movements and habits may be observed.

Several species that are not easily reared in small aquaria may do very well in a garden pond, but in the latter they are not generally so easily watched as in a glass tank.

We have already dwelt on the importance of maintaining conditions for our aquarium pets as closely as possible corresponding with those under which we find them in nature, and this is especially important in the case of fishes.

Some, such as the Bullhead, delight in shallow and rapid streams with stony bottoms, while others are found in the deep and muddy holes of sluggish rivers or among the weeds of still or running water. And though some species do well under conditions more or less at variance with those which are natural to them, yet it will be wise to follow nature as closely as possible, even though by so doing we may find observation less easy, and possibly also cause our aquarium to look rather less picturesque than we would have it be.

Again, if we are not acquainted more or less with the habits of fishes before we venture to put different species together, we must be prepared to gain experience at the cost of the loss of some of our specimens. Some species will prey on others, fish constituting their natural food; and others are exceedingly pugnacious, and always ready to attack out of mere ferocity.

I have placed a small Jack, one about nine inches long, in an aquarium with several Roach and Carp almost as large as itself; and although they lived together for several months, and the Jack was well supplied with suitable food, yet their life was not one of peace, and the grazed flesh of the harmless species, exhibited in spots where the scales had been torn away, showed the advisability of removing the Jack to other quarters. In this case the marks of injury left not the slightest doubt that the Jack had frequently endeavoured to perform an impossible act—to swallow a fish of almost equal size to itself—although I had never caught it in the act.

No fish has become such a universal favourite for the aquarium as the Gold Fish or Golden Carp (*Cyprinus auratus*). This fish is said to have been introduced into England from China in the early part of the seventeenth century, and it has now become so far acclimatised that it weathers our severest winters in outdoor waters.

It is certainly a very pretty fish, and its value is enhanced by the great variability in its colouring, the bright orange tint being often relieved by patches of black, brown, or white.

Like the Common Carp (*Cyprinus carpio*) of our ponds, it is quiet and inoffensive, feeding on small worms and insects and on

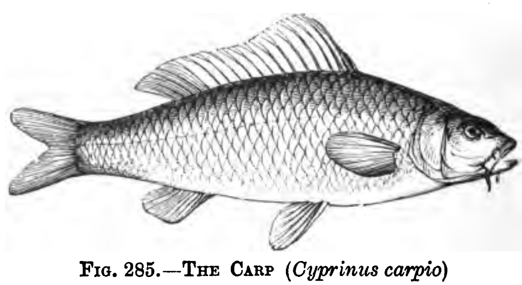


FIG. 285.—THE CARP (*Cyprinus carpio*)

the young shoots of various pond plants, and displays marked gregarious tendencies.

Both these species are valuable in the aquarium; for, being almost always on the move, they give life to the scene when other inmates are hiding under the shelter of stones or weeds. For the same reason they are useful fish with which to stock a small garden pond. They sport about at and near the surface, chasing each other among the floating and standing weeds, and occasionally taking a leap into the air.

There is no difficulty in obtaining Carp for the aquarium. Young ones will be frequently found in the net that has been dashed among pondweeds when striking for aquatic insects, and those taken with the rod and line are generally so slightly injured as to be apparently none the worse. A red worm is a satisfactory bait, and as a rule the carp bites freely.

For small aquaria the Minnow (*Leuciscus phoxinus*—Plate VI, fig. 2) is admirably adapted. It is very prettily marked, especially during the breeding season—early in May; but if it is required to breed Minnows in captivity, they should have plenty of room and be well fed, or, like many other fishes, the Carp included, they will devour their own young.

Minnows prefer running water, and if kept in captivity should be provided with a permanent fountain, with of course a pipe to carry off waste.

The Roach (*Leuciscus rutilus*) also thrives well in captivity, provided the aquarium is adapted to the size of the specimens

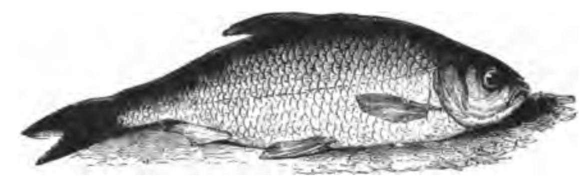


FIG. 286.—THE ROACH (*Leuciscus rutilus*)

obtained. It is not so easily caught as the Carp, being very suspicious, and inclined to avoid the angler's float. It is also very particular as to its food, but will usually bite at gentles (the larvæ of the Meat Fly), or at boiled wheat grains. The finest tackle should be used by the angler.

I have not space to enter into particulars concerning the majority of the species belonging to the present sub-order, but will refer briefly to one or two of the bottom fish—those heavy-bodied fish which lie on the bed of the pond or stream, and which cannot rise without a considerable amount of exertion.

Such fish are usually provided with barbules on each side of the mouth, and their bodies are not compressed laterally.

One of these, the Gudgeon (*Gobio fluviatilis*—Plate VI, fig. 1), I have found thrive well in a large aquarium, where it delights to lie with its kind among the densest weeds, often remaining perfectly still for a long time together.

Gudgeons have been described as purely animal feeders, but in captivity at least they feed readily on bread crumbs and other vegetable diet, swimming up to the surface to snap at the floating food as soon as it is thrown to them.

But perhaps the most interesting of the bottom fish is the Common Loach (*Nemachilus barbatulus*). It is to be caught in many small ponds and ditches, and is sometimes found in such a small quantity of water that no apparatus is required to catch it, for it is unable to get beyond the reach of the hand. In any case there is generally no difficulty in obtaining it by means of the ordinary pond net, which should be made to scrape along the bottom.

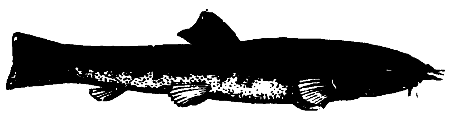


FIG. 287.—THE LOACH (*Nemachilus barbatulus*)

Although essentially a bottom fish, the Loach will frequently rise to the surface, and even remain there for some time, providing it has a suitable resting place. If kept in a small aquarium, I should advise the introduction of a root of *Potamogeton natans*; or, if in a small pond, either this or one of the Water Lilies. The floating leaves of these plants form admirable supports for the Loach when it desires an airing and sunning, and thus enable us to watch and feed it with ease.

The *Actinopterygii* include a few of our freshwater species. They are so called because of the radiating or fanlike disposition of the fin rays.

Two of these belong to the Perch family, and these are the Common Perch (*Perca fluviatilis*—Plate VI, fig. 4) and the Ruffe or Pope (*Acerina cernua*). These are very similar, and both are to be caught in sluggish streams.

The Perch is certainly one of the prettiest, if not the prettiest, of our freshwater fishes, and is a perfect ornament in the aquarium;

but it does not seem to take so kindly to captivity as many other species.

It is a very voracious fish, and feeds readily on worms, small frogs, tadpoles, minnows, and the fry of other fishes.

For voracity combined with pugnacity, however, we shall hardly find a match for the Common Stickleback or Three-spined Stickleback (*Gastrosteus aculeatus*—Plate VI, fig. 5). It will eat almost every living thing that comes in its way, provided it is small enough to be swallowed; and even when it is not, the fish will often struggle hard to devour it before the case is finally given up as hopeless.

The pugnacious character of this little creature is seen to perfection when a worm, about twice as long as its own body, is thrown into its home. The wriggling worm is seized, regardless of its dimensions, without the slightest hesitation, and the Stickleback at once commences its impossible task. Others appear on the scene immediately, and then a fierce quarrel commences. The holder of the worm tries to carry it off to avoid the interruption of its companions, but is pursued by them, and shortly we find three or four tugging at the poor worm, while perhaps a dozen others are fighting for their share of the feast. All have their three strong dorsal spines erected in readiness for the offensive, and it is not at all uncommon, on such occasions, for one, furious and disappointed, to strike one of its fellows from below, and literally rip up its body, and then, leaving it in its death struggles, to renew the chase for the prize. And so the fight continues, till at last the poor worm has been killed, torn to fragments, and eventually devoured by the voracious group.

But it is not only at feeding time that this pugnacity is displayed. Simply plunge the end of your stick into the water where the Stickleback swarms, and the intruding rod is charged with such force that you can even feel the blows given to it by their bony jaws, the charges being renewed every time the stick is moved. It will also attack fishes very much larger than itself, frequently dealing a deathblow to the victim that ventures within its precincts; and even the largest of the water snails are charged by its powerful jaws if they venture to expose their soft bodies within its range.

No instructions need be given for the capture of this pugnacious but interesting little king of the ponds. We are all familiar with the schoolboy's method of dangling the tempting worm on the end of a yard or so of cotton thread. He needs no hook; but simply allows the Stickleback to swallow the worm, or part of it, and then suddenly jerks the fish out of the water before it has had an opportunity of disgorging its meal. But here is a simple method of securing a considerable number in a short time: Place your pond net, rim uppermost, about a foot below the surface of the water. Then introduce the end of a stick, and keep it moving just above the net till a group of the infuriated 'Titlers' are busily engaged in the charge, and a sudden upward stroke of the net will then secure them all. Thus we need no bait, in the usual sense of the term, but merely turn their natural pugnacity to our own account.

It is during the breeding season in early summer, however, that the Stickleback is most interesting. At this period the male is adorned with the most brilliant colours; and then, too, his fury knows no bounds. He constructs a rough nest for his bride by matting together any fibrous materials at hand. Within this nest the female deposits her eggs; and from this time till the young have hatched and dispersed to seek their own livelihood he will never leave his charge, day or night, and will furiously attack any moving thing that ventures within a foot or so of the nursery.

Although the Stickleback is apparently so hardy and strong, yet it requires some care in confinement. The aquarium with a number of these fish as inmates is sure to be a scene of continuous battle and slaughter unless they have plenty of room; and of course it will not be safe to introduce with them any other small and harmless species. Again, if it is desired to watch the construction of the nest and the parental care of the male, it will not do to have more than one or two pairs in the same vessel unless it is very large and well supplied with weeds, the use of the weeds being not only for the aëration of the water and the supply of materials for the construction of the nest, but also to serve as a kind of barrier between the sacred areas of the jealous parents.

We have already said that the Stickleback is not particular as to its food—that it will devour almost any living creature, provided it can swallow it, and herein lies another consideration to be borne in mind when introducing this fish into aquaria or ponds in which we intend to breed and rear other species; for the Stickleback will eat any spawn that comes in its way, and the newly hatched fry from the eggs that escape its notice stand very little chance of attaining any size in its company.

The only other freshwater fish we need notice is the Common Bullhead or Miller's Thumb (*Cottus gobio*), which belongs to the same family as the marine Gurnard. This fish is not by any means ugly, though, as one would surmise from the first popular title, its head is rather out of proportion. The origin of the second of these names is not far to seek, for the head is flat and broad, somewhat resembling the shape of a miller's thumb, flattened by its frequent application to the meal-spout to test the quality of the flour; and as this little fish is very partial to the small rapid and stony streams that so often drain millponds, those familiar with the mill and its neighbourhood have not failed to note the likeness just mentioned.

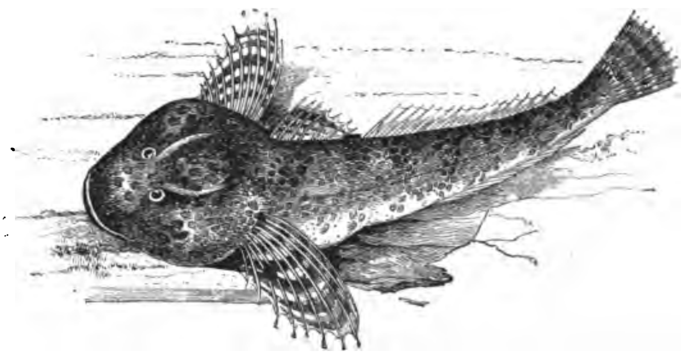


FIG. 288.—THE BULLHEAD (*Cottus gobio*)

Although the habits of the Bullhead are interesting, it does not often display itself in the aquarium; for it spends nearly the whole of its time in hiding under stones, and seldom shows itself except when it darts after a passing insect, crustacean, or other small creature on which it preys. In the evening it will exercise itself, but even then its excursions are short and almost entirely confined to a sort of shuffling movement from one hiding place to another.

The Miller's Thumb may be easily taken by hand in shallow water, but the best way to secure it is to scrape up the bottom of the stream it inhabits with a strong net, when a mixture of stones, gravel, and fish will generally be obtained.

The fish may be readily identified by means of our illustration and the characteristics mentioned above, but I will also call attention to the bony spines at the sides of the head, and the strongly developed pectoral fins which assist the creature as it creeps, as it were, along the bottom.

CHAPTER XII

AMPHIBIANS

We have yet another class of animals to consider in connection with freshwater life, and this is the *Amphibia*, which includes Frogs, Toads, and Newts.

The word *Amphibia* signifies 'double life,' and under this head we place those creatures that spend a portion only of their existence in water. But, before we go any further, it will be necessary to give a word of explanation in order that we may learn to use the above term in its proper restricted sense.

We have already studied many creatures that are only temporarily aquatic. Thus we have seen that certain spiders are almost equally at home both in water and on land, and that numerous insects are truly aquatic only during their earlier stages, and that some of these, in their perfect forms, pass freely from ponds and streams into the air or on to the land. We have also several mammals, such as otters, water rats, beavers, and seals, that are often spoken of as amphibious on account of their partially aquatic habits. Many birds, too, have very marked appreciation for either fresh or salt water, some being expert swimmers and divers, while others prefer the shallow waters of marshes and fens. Yet none of these creatures belong to the *Amphibia*. This class contains only those vertebrates that are specially provided with breathing organs which render them particularly adapted for direct respiration—that is, for acquiring the necessary air supply direct from the atmosphere; and also for the absorption of air that is dissolved in the water in which they are at times submerged. In other words, the members of the *Amphibia*, during at least a part of their existence, possess gills which enable them to breathe under water just as fishes do; and also, in the adult stage, possess lungs that permit the direct absorption of oxygen from atmospheric air inhaled after the manner of the higher animals —ourselves included.

The true amphibians are cold-blooded creatures which are developed from eggs, and exhibit, in their earlier stages, a rather close relationship to the fishes. Only a few of them can be described as large animals, and of all the five classes of the *Vertebrates*, the *Amphibia* contains the fewest species.

The reader has probably observed that in some of the older works on natural history the animals which we now call Amphibians are included, with snakes, lizards, and tortoises, under the head of *Reptilia* or Reptiles; but, although they resemble the latter in several important features, they differ materially in that they undergo remarkable changes as they pass from their early to their adult stage—changes which are so striking as to justify the formation of a separate class for the reception of frogs, toads, newts, and their allies.

Let us take a general view of this interesting class, tracing the Amphibian through those metamorphoses which may be regarded as the most important characteristic of the group.

When the young one first emerges from the egg it is a little dark-coloured limbless creature with a large 'head' (really head and body together) and a long tail. In this state it is spoken of as the tadpole or larva; and from this period it undergoes a regular series of metamorphoses till the adult form is attained. These changes at once remind us of the more familiar metamorphoses of insects; but while the latter frequently pass through an intermediate passive and dormant stage known as pupa or chrysalis, the Amphibian is very active in all its various states, and it exhibits no apparently sudden transformations like those so commonly observed in insect life.

Although somewhat fishlike in form, the young Amphibian has generally no covering of scales, but its skin is smooth and very soft, the outer layer being very little developed. It also differs from fishes in having no true fins, but it frequently possesses a substitute for these organs in the form of membranous fringes which, in some species, disappear before the adult stage is reached, and in others are persistent throughout the creature's existence. It further resembles a fish in the possession of membranous sacs which contain air, corresponding with the air bladder or swimming-bladder of the latter, by which the specific gravity of the body may be slightly altered to suit varying circumstances. At this stage, too, its heart consists of only two chambers—an auricle and a ventricle—in which feature it displays yet another proof of its cousinship to the finny tribe.

The breathing organs of the tadpole consist of external gills, by which oxygen is absorbed from the water in which it now lives. The digestive tube is long and coiled spirally.

As the tadpole gradually develops into the adult stage of its particular species, various changes, both in external form and in internal structure, are progressing simultaneously. The air sacs become larger, and a rich network of blood-vessels is developed within their substance, till at last they become a pair of lungs by which the creature is enabled to breathe out of the water. At the same time, in some species, the gills gradually disappear, so that the mature animal can no longer breathe while under the water; but in others the gills are retained throughout the whole existence. In both cases, however, the creature is not entirely dependent on these special respiratory organs for its necessary supply of air, for the skin is always soft and moist, and capable of absorbing air, either direct or from the water in which the creature lives or rests.

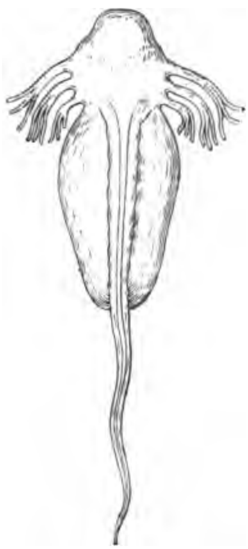


FIG. 289.—THE YOUNG TADPOLE OF THE COMMON FROG (*Rana temporaria*), ENLARGED; SHOWING THE EXTERNAL GILLS

FIG. 290.—THREE-CHAMBERED HEART OF THE ADULT FROG, ENLARGED
a, auricles; *v*, ventricles

While these changes are progressing, the two-chambered heart of the tadpole develops a second auricle on the left side for the reception of the aërated blood from the breathing organs, the right auricle receiving the darker blood that has just completed its circulation in the various parts of the body. The digestive tube gradually becomes proportionately shorter and less coiled. In most species, too, two pairs of limbs appear, and in some cases the tail is gradually absorbed, while in others it persists throughout the whole lifetime, and becomes a useful and sometimes very ornamental appendage.

In the higher *Amphibia* the skeleton of the adult is remarkably well developed. The vertebræ form moveable ball-and-socket joints, but the ribs are either small or entirely wanting.

One more striking feature of the Amphibians is worthy of notice. The corpuscles or blood-cells are remarkably large. In one species—the blind Proteus that inhabits the dark caves of Carinthia—these cells, which are oval in form, measure as much as $\frac{1}{400}$th of an inch in length.

FIG. 291.—THE UNDER SIDE OF THE TADPOLE OF THE FROG, SHOWING THE COILED DIGESTIVE TUBE, THE SUCKERS, THE INTERNAL GILLS, AND THE RESPIRATORY APERTURE, ENLARGED

The class *Amphibia* is divided into three orders, as follows:

1. *Gymnophiona*—limbless creatures resembling earthworms in form and habits. Their bodies are ringed like those of worms, but the skin is usually covered with scales. They live in burrows in the ground, and their eyes are rudimentary. This order contains only a few species, and these all inhabit tropical countries.

2. *Urodela*—the members of which possess limbs and a permanent tail. This order is divided into two sections—

(*a*) Those in which the gills of the tadpole stage are retained throughout the whole or greater part of their life, and in which lungs are gradually developed as the adult stage is reached. This section has no British representative, but includes the *Proteus* already mentioned, also the two-limbed *Sirens* or '*Mud Eels*' of Carolina, and the four-limbed *Axolotl* of Mexico.

(*b*) The second section, in which the gills disappear as the lungs are developing, is far more interesting to us, since it contains the Newts and Salamanders that abound in our ponds and ditches.

3. The third order—*Anura*—includes all those Amphibians that are without tails in the adult stage, and is well represented by our Frogs and Toads.

The British Amphibians number only seven species, which may be classified as follows:

Class AMPHIBIA.

Order URODELA or CAUDATA.

Family SALAMANDRIDÆ.

1. *Molge cristata* (*Triton cristatus*)—The Great Warty Newt.
2. *Molge vulgaris* (*Lophinus punctatus*)—The Common Smooth Newt.
3. *Molge palmata* (*Lophinus palmatus*)—The Palmate Newt.

Order ANURA or ECAUDATA.

Family RANIDÆ.

4. *Rana temporaria*—The Common Frog.
5. *Rana esculenta*—The Edible Frog.

Family BUFONIDÆ.

6. *Bufo vulgaris*—The Common Toad.
7. *Bufo calamita*—The Natterjack Toad.

The Common Frog (*Rana temporaria*)

(Plate VII, fig. 1)

The general plan of this book has been to work *up* the scale of life, from the lower to the higher forms; and, to be consistent in the present chapter, we should study the Newts before the Frogs. But the Common Frog is generally so much better known than the other British Amphibians, and forms such a splendid type of its class, that I am tempted to make one trifling deviation from the plan in order that we may study the species in what seems to be a more convenient order.

In the spring-time, usually about the beginning of March, but sometimes earlier or later according to the forwardness or backwardness of the season, Frogs may be seen in ponds and ditches,

PLATE VII.

1

3

2

West, Newman imp.

where they have congregated for the purpose of depositing their eggs; and towards the middle or end of the same month large masses of a jellylike substance, containing numerous black spots, may be seen floating on the water, sometimes in such quantities as to almost completely cover the surface.

These eggs are laid in one continuous string, the black and white

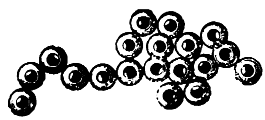


FIG. 292.—EGGS OF THE FROG, JUST LAID

embryos being all held together by the gelatinous envelopes. At first the gelatinous envelopes are not very thick, and the newly laid eggs, which are only one-sixteenth of an inch in diameter, lie on

FIG. 293.—EGGS OF THE FROG, A FEW HOURS AFTER LAYING

the bottom of the pond; but in a very short time the envelopes swell out till the diameter of each egg is from a quarter to three-eighths of an inch.

After a few hours the embryo or yolk begins to divide into segments or cells—a process which may be easily observed under the microscope. At first a depression divides it into halves, and shortly after another one, at right angles to the first, forms four divisions. Next follows a third depression that runs transversely round the yolk, nearer one 'pole' (crossing point of the first two depressions) than the other. Then there appear other longitudinal and transverse divisions, till the yolk is at last broken up into a mulberry-like mass of cells.

While these changes are progressing, a cavity begins to form, and around this the cells soon arrange themselves in layers, those

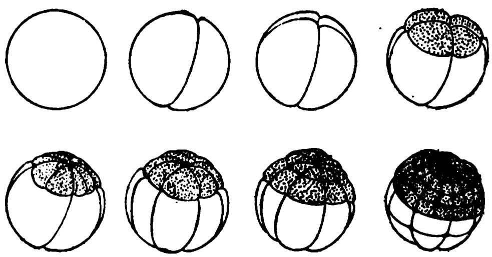


FIG. 294.—VARIOUS STAGES OF THE PROCESS OF THE SEGMENTATION OF THE YOLK, MAGNIFIED

of the upper part becoming very dark in colour, and more regular than the others.

Soon the darker regular cells, which have become much smaller

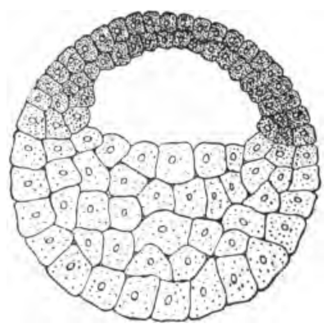


FIG. 295.—SECTION THROUGH A FROG'S EGG, SHOWING THE INTERNAL ARRANGEMENT OF THE CELLS, MAGNIFIED

than the others by repeated divisions, spread over the whole of the surface; and two distinct strata are formed, the outer one of which gives rise to the external skin and the brain and spinal cord, while the inner layer is that which forms the delicate lining of the food passage. Between these two layers are the cells from which all the other parts of the body are evolved.

A groove is now formed on the upper surface of the embryo, the

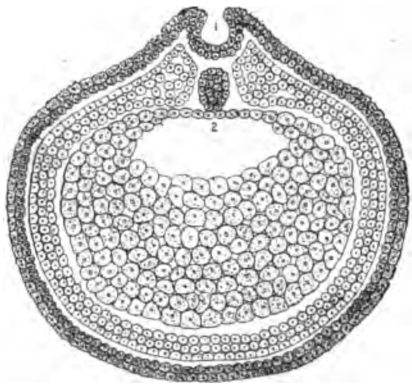


FIG. 296.—A SECTION THROUGH THE EMBRYO AT A LATER STAGE, SHOWING THE THREE LAYERS OF CELLS, MAGNIFIED

1, the primitive groove; 2, the notochord, representing the future backbone

sides of which eventually unite so as to form a canal or tube which is destined to contain the brain and spinal cord. And so the gradual development proceeds till, at the end of twelve or fourteen days, the little embryo has become a fishlike tadpole, ready to make its way out of the gelatinous covering and start in life on its own account.

But although these interesting changes are to be observed only

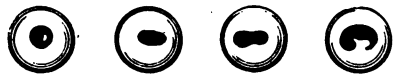


FIG. 297.—THE DEVELOPMENT OF THE FROG EMBRYO AS OBSERVED WITH THE UNAIDED EYE, NATURAL SIZE

by the aid of a microscope, yet there are outward signs of development that are easily seen with the naked eye. About a week after the eggs have been laid, the dark embryo is no longer spherical, but oval in form; and two or three days later it begins to exhibit a well-marked division into head, body, and tail. At this stage, as it lies coiled up within its transparent envelope, it looks more like a little fish than a frog.

Now two pairs of little branched tufts appear at the sides of the neck, followed, after a brief period, by a third pair. These are the external gills by which the creature is to obtain its supply of air when it is free.

FIG. 298.—THE YOUNG TADPOLE SHORTLY BEFORE HATCHING, MAGNIFIED

About two weeks have now passed since the eggs were laid, and the tadpoles may be seen wriggling about in a restless manner within their gelatinous spheres. Then, one by one, and in rapid succession, the numerous members of the same brood break loose through their weak prison walls, and, for a time, play round about their vacated homes, sporting and resting alternately. They very soon show their gregarious tendencies by collecting in dense clusters on the surface of pondweeds or any convenient objects, holding on by a pair of suckers on the under side of the head (fig. 299). These clusters at once become the scenes of an almost constant turmoil. So strongly marked is their desire to put their heads together, that each one who is so unfortunate as to be for a moment on the outer edge of the cluster, immediately loosens its hold, and struggles for a place nearer the centre, wedging itself in between its companions with a smart wriggling of its tiny body, and almost invariably displacing one or two, thus compelling them to do as it had done. And so there seems to be an almost perpetual struggle for a good position.

FIG. 299.—A GROUP OF VERY YOUNG TADPOLES

Now, if all these vigorous efforts were made in order to relieve the pangs of hunger or to secure some tasty morsel, no further explanation would be necessary; but the young tadpoles indulge in this seemingly selfish process of turning their neighbours out of doors when no food is at hand; nay, more, even before their mouths are formed! We can therefore ascribe such behaviour only to an instinctive gregariousness.

During the first few days of the tadpole's life it does not, nor cannot, eat any food, but is sustained by the remains of the 'food-yolk' within its own body, on which it thrived before leaving the egg, and which is still unexhausted at the time of its exit. But now the mouth appears; bordered by lips with horny projections, and armed with a pair of horny jaws.

It now commences to feed vigorously on a vegetable diet, devouring confervæ and other low forms of plant life, and rapidly increases in size.

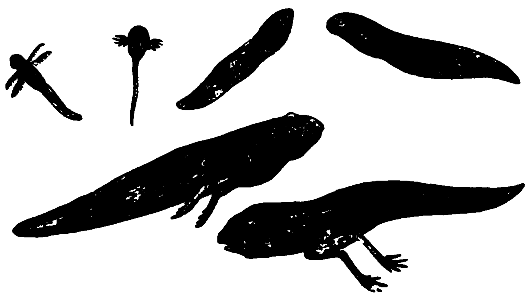


FIG. 300.—TADPOLES IN VARIOUS STAGES, NATURAL SIZE

Important structural changes accompany this rapid growth. The food canal, which was previously short and wide, speedily develops into a long coiled tube (fig. 291), and the glands (liver and pancreas) which secrete the digestive fluids soon enlarge and become active.

At the same time the respiratory organs are undergoing remarkable modifications. Four little slitlike apertures, called the gill clefts, are formed on each side of the neck. These communicate with a cavity at the back of the mouth, and their edges, turning inwards, develop into internal gills. While these changes are progressing, the external gills gradually become absorbed, and a flap of skin grows backward from each side of the head, covering the gill clefts, and finally enclosing them in a cavity called the gill chamber. Then the fold of skin (called the operculum or gill cover) on the right side unites with the outer covering of the body, completely shutting in the gills, while that of the left side only partially closes, leaving an opening (fig. 291) by which the water taken in at the mouth for respiratory purposes can find its exit from the gill-slits on both sides.

FIG. 301.—THE TADPOLE WITH ITS LIMBS IN PROGRESS OF DEVELOPMENT—THE FRONT PAIR BEING STILL CONCEALED UNDER THE GILL COVERS

The tadpole is now about a month old, and has reached a total length of about one inch. Its body is round, and its tail long and supplied with broad membranous fringes above and below. It swims rapidly by an undulatory movement of its powerful tail, and no longer uses its suckers; in fact these organs, like the other temporary appendages, have so degenerated as to become useless.

The future limbs next begin to appear. The first sign of these is a pair of small projections at the base of the tail. These gradually develop. A few weeks later they are well formed, the toes appearing after the legs have exhibited a distinct division into joints. The forelimbs *appear* later, though they are actually formed at the same time as the hind pair, for they are at first hidden beneath the folds of skin that cover the gill clefts. The right one breaks through this skin, while the left forces its way through the opening on that side for the exit of the water that circulates in the gill chambers.

But while the four limbs are developing, a number of interesting modifications are in progress in various parts of the tadpole's body. After a short period of less activity, the whole of the outer skin is shed, together with the horny jaws, and the eyes are for the first time fully exposed. The mouth, which was before round and small, now becomes gradually wider, and the tongue very much larger. The lungs are developing, and for a time the creature breathes both by lungs and gills, occasionally coming to the surface for a small supply of air. Then the gills entirely disappear and the clefts close up, so that respiration is carried on by the lungs only. The digestive organs also take part in the wonderful transformation. The stomach and digestive glands become much larger, while the intestinal tube, which we observed to be long and coiled in the earlier stage, now shortens considerably, at the same time becoming narrower. The diet is also changed in accordance with the new capacities of the digestive apparatus, the former vegetable food being entirely discarded for an animal regimen.

Finally the hind limbs grow very long; the foot becomes long, slender, and webbed; the tail, which has for some time been gradually diminishing, is completely absorbed; and the creature, now a perfect frog, wanders from its pond or ditch among the moist grass, searching for worms and insects, and occasionally returning to the water in dry weather to moisten its delicate skin.

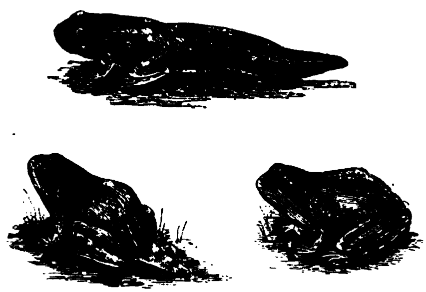


FIG. 302.—YOUNG FROGS

Now that we have traced the frog through its metamorphoses, let us proceed to learn something of the more interesting characteristics of the perfect form, and observe some of its movements.

In the first place let me say that frogs are almost always very easily obtained, and very easily reared in all their stages, so that any one who desires to study them cannot do better than keep them as pets either in the garden or in some prepared home. If your garden is surrounded by a wall such as would prevent the escape of your captives, then, with the expenditure of only a little time and labour, you can keep your frogs under perfectly natural conditions, allowing them all the comforts and freedom of the wild state.

If this is to be your plan you must prepare a pond similar to that recommended on page 85, but see that the edges are such that the frogs can easily walk out of the water; also have your rockery so loosely piled that the amphibious creatures will have no difficulty in finding a nook in which to hide during the daytime.

Although such an arrangement is certainly the best you can possibly have for the frogs themselves (and I need hardly say that it answers equally well for newts and toads), yet it is not always the most convenient for the naturalist; for the creatures have such a clever way of concealing themselves during the daytime, and especially in dry weather, that they are not always to be found when wanted for observations. But even when it is necessary to keep a few specimens in closer confinement for the observation of their habits, it is still a good plan to have a reserve in a wild or semi-wild state close at hand. It is well to remember, too, that the amphibians are perfectly harmless to fishes, and that both may consequently be reared in the same pond as far as the safety of the latter is concerned; but many of our freshwater fishes readily devour tadpoles, so that, unless you start with a good number of the amphibious larvæ, all will disappear before they have reached an age at which they can protect themselves by leaving the water.

Tadpoles should have plenty of room; and if a suitable pond cannot be provided, let them have a large tub of water, well supplied with aquatic plants; and then, when they give evidence of the final change in the respiratory organs by coming to the surface to breathe, they must be immediately removed to a pond, or be provided with some means by which they can easily quit the water when their truly aquatic life is at an end.

When the metamorphoses are over—that is, when the young frogs have assumed the form and habits of the adult—they may be kept in any kind of case or house, providing they have a small supply of water, changed at frequent intervals, a few piled stones for shelter, and a layer of turf or growing moss. They may be made very comfortable in a greenhouse, fern case, or any form of large glass vivarium, providing these conditions are maintained; but if thus confined they must be well supplied with food—worms, grubs, beetles, &c.

Frogs and toads are often kept in greenhouses for the sole purpose of keeping down the insects that are so destructive to plants, and it is too often assumed that the creatures so confined have plenty to eat. It must be remembered, however, that the floor of a greenhouse is often composed of a material through which worms cannot burrow, and that the florist's plants are frequently placed in such a position that the frogs and toads cannot reach the insects that feed on their leaves. Under these circumstances it is as much the duty of the owner to feed his frogs as to water his plants.

Now let us note some of the more interesting points in the structure and habits of frogs that have not been previously mentioned in our account of their metamorphoses.

Look at its skeleton—a splendid type of the internal framework of the vertebrate animals. The backbone, with which all the other bones are directly or indirectly connected, consists of nine ringlike vertebræ, all jointed together in such a manner as to form a flexible column, and behind these a long narrow bone—the *urostyle*—extending backwards almost to the hindermost extremity of the long bones of the hip or *pelvis*. The skull, it will be observed, is very wide, with only a small tubular cavity in the middle to contain the brain; and the lower jaw is so extensive as to admit of a very wide gape. Teeth exist in the upper jaw and on the palate or roof of the mouth, there being none on the lower jaw. They are very small—perfectly useless for mastication or chewing—but are provided with sharp, hooked crowns that enable the creature to hold its larger victims secure while they are being gradually devoured alive.

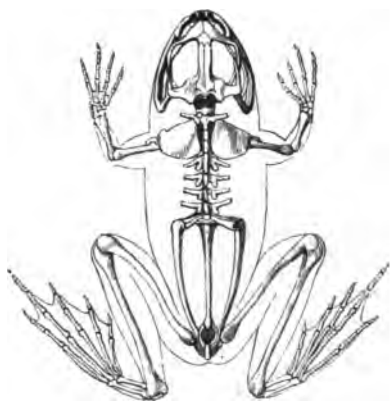


FIG. 303.—THE SKELETON OF THE FROG

The shoulder girdle surrounds the front portion of the vertebral column, but is connected with it only by muscles and ligaments; so that in a prepared skeleton it is, together with the arms and breastbone, quite disconnected from the rest of the bones.

The arms are attached to the shoulder by means of a ball-and-socket joint, the rounded head at the top of the upper arm fitting into a cavity of the girdle. The little bones of the wrist and hand are beautifully formed and jointed, and correspond very closely with our own in structure and arrangement.

When a frog is at rest, its back often exhibits quite a prominent hump near the middle. This is not due to any sudden bend in the backbone itself, for this is always very nearly straight, but is caused by the oblique arrangement of the long bones of the hip. The fore extremities of the latter are jointed to two large projections which extend upwards and outwards from the ninth vertebra, and from these the hip bones curve downwards to the hinder end of the body.

The structure of the legs is very similar to that of the arms, but the former are much longer, and, moved as they are by very powerful muscles, they enable the frog to take prodigious leaps on land, and to swim with considerable speed in the water. The length of the foot is remarkable, and is due not only to the presence of very long bones in the toes and what we should in our own case term the instep, but the heel and ankle bones are also considerably elongated.

There is one other peculiarity of importance in the skeleton of the frog, viz. the absence of ribs, so that all the internal organs that lie behind the shoulder girdle are protected by soft structures only except where covered by the backbone and pelvis.

Every one who is interested in the internal structure of the frog should prepare for himself a complete skeleton. By so doing he will certainly learn much, and the specimen will always be valuable as a work of reference as well as an object of beauty. The process is simple, requiring patience rather than skill.

Open the abdomen of a dead frog with a penknife or a pair of sharp-pointed scissors. Remove all the internal organs, and cut away all the skin and flesh. Thus in about half an hour or so you will get the bones comparatively cleared. Of course you have to be careful not to cut any of the bones, also that you do not in any way injure the cartilages. The latter, in fact, are to be preserved with the harder parts of the framework. The ligaments also, which bind the bones together at their joints, should be left intact.

When the skeleton has been roughly cleared as above directed, it should be soaked for a time in hot water. This will soften the small quantity of flesh that remains, and then the final cleaning can be performed with the aid of a soft brush, using a small pair of scissors occasionally to cut off the projecting tendons.

The shoulder girdle, together with the arms, will become detached. The lower jaw also will probably become disconnected. But these, and other parts that may be separated during the final cleaning, can easily be fixed together again by means of a little coaguline after the whole is dry.

When the clearing operation is all over, transfer the skeleton to a sheet of cork, and, after supporting it in some attitude natural to the living creature by means of pins and pieces of cork, set it aside to dry.

The exigencies of space will not permit of a detailed description of the arrangement, structure, and functions of the various internal organs of the Frog, so we shall have to confine our observations to the more obvious features that are likely to attract the attention of young observers.

Let us watch the inmates of our vivarium as they rest in their shallow little pool, with perhaps only so much of the bodies above the surface as is necessary to expose their prominent eyes and nostrils to the air. Or it may be that we shall have to look for them in a cosy little corner that has been hollowed out into a comfortable cradle by a vigorous scratching and shuffling of their long hind legs, where they lie hidden from view under a layer of soft green moss.

The smooth soft skin, though very variable in colour, is always more or less mottled with a darker tint on the upper surface, and these darker markings always include a patch on each side extending from the eye to the shoulder.

The ground colour varies in different individuals, and also in the same creatures at different times. Sometimes it is a very pale yellow, on which the darker markings stand out boldly, giving a very pretty contrast; but in other cases it is very dark—almost a black, on which the mottlings are hardly visible. I have at the present time, among my pets, frogs exhibiting remarkable extremes in this respect, including both the lightest and the darkest ground colours I have ever observed in the species. And it is noteworthy that all the dark specimens were taken in or near ponds situated in rather dark shady corners, with beds of black mud, and surrounded by a very dark soil; while the very light ones were all taken in open grass lands with a light yellow clay soil. Thus in both cases the creatures were undoubtedly protected more or less by their resemblance to the surrounding colours. It must be observed, however, that the colours of any one individual are by no means permanent, the same frog often appearing in new tints several times during the course of a few days.

Just behind the eye, in the middle of the dark patch mentioned above, is a dark circular membrane, supported by a firm ring that surrounds it. This is the *tympanic membrane* of the frog's ear, by means of which the vibrations of the air are transmitted to the internal ear.

FIG. 304.—HEAD OF *Rana temporaria*, UPPER SURFACE

As we watch our frogs we observe the floor of the mouth of each one perpetually rising and falling, and the nostrils alternately opening and closing. These movements are connected with respiration—a function that is performed in the case of the frog in a very different manner from the same function in ourselves. A frog cannot breathe with its mouth open; and it necessarily follows that death from suffocation must result if its mouth be kept open for a considerable time.

The breathing of the frog through the agency of the lungs is carried on as follows: The floor of the mouth is depressed, thus making the cavity of the mouth larger, while the nostrils are open. In this way air is made to enter the mouth, through the nostrils, just in the same manner that it is made to enter the cavity of a pair of bellows or a force-pump through the valve. The floor of the mouth is then forcibly raised by muscular action while the nostrils are closed, so that the air, thus driven from the mouth, and having no other outlet, is forced into the lungs—an action which also finds its counterpart in the bellows and force-pump. The expulsion of this air from the lungs—expiration—is then brought about by a contraction of the muscles of the flank, which cause the internal organs to exert a pressure on the lungs, and is assisted by the contraction of muscular fibres that exist in the walls of the lungs themselves.

In our own case a cessation of the regular movements of respiration would cause death in a very few minutes; but such would not be the result in the case of a frog. We are entirely dependent on the lungs for the aëration of the blood, but the frog is provided with a second means of respiration in its soft, moist, permeable skin, through which air readily passes into the dense network of minute blood-vessels that lie immediately beneath. Hence it is probable that a frog would continue to live for some considerable time after the complete cessation of its pulmonary respiration.

While speaking of respiration it may be well to call attention to the cruelty so often unwittingly practised by inexperienced aquarium owners of keeping frogs in an ordinary aquarium where the creatures have no resting place close to the surface of the water. In such a case the poor frogs never get any perfect bodily rest. If they succeed in finding a hiding place at the bottom of the aquarium they are compelled to rise at frequent intervals for the necessary supply of air; but they will more often allow themselves to float on the surface, perpetually making vain attempts to get a foothold above the water, and frequently struggling to keep their nostrils in the air. Frogs are not aquatic creatures, and will never live long in an ordinary aquarium. On the other hand, they should always have a small supply of clean water in which they can have an occasional bath to keep the skin moist in order that it may perform its respiratory function. Failing this supply, unless they are provided with a hiding place that is perpetually damp, the skin will become dry and hard, and death speedily follow. If the vivarium is kept indoors throughout the winter, and so protected from the low temperatures to which frogs are exposed in their wild state, then they will not hibernate, but will make their appearance night after night, except perhaps in very severe weather, and take a ramble round their little home, occasionally indulging in a small meal if their wants in this direction have been studied. Under these circumstances, too, they retain their amphibious characteristics all through the cold season, sometimes remaining hidden for days together, but occasionally taking to the water, and resting for longer or shorter periods almost entirely submerged.

As we watch them at this season of the year we observe that their eyes are sometimes closed, the prominent eyeballs having been retracted, and the lids drawn completely over them. But let us select a wide-awake pet to see how these movements are brought about. We touch its prominent visual organ gently with the finger. At once the ball is pulled in by muscular contraction, and at the same time the upper lid descends, but only a little way, and the lower one, which is far more mobile, rises to meet it. But as soon as the finger is removed the lids are withdrawn, and the retractile ball again resumes its prominent position.

The croaking of the Frog is produced by the vibration of two *vocal ligaments* which correspond with the so-called vocal cords in our own bodies. These sounds are often described as anything but musical, but for my own part I regard the concert given by a number of these amphibians during the still hours of the evening as decidedly pleasant. During the hibernating period frogs are as silent as they are still, but our indoor pets treat us to an occasional note at this dull season. This, however, is not a spontaneous serenade such as that with which the creatures so lavishly greet one another during the breeding season in early spring, but only an expression of resentment at some unwarrantable intrusion. Thus one of the inmates, making a tour of inspection round its case, with of course the usual attempts to walk straight through the clear glass, and paying not the slightest respect to any of its fellows, walks deliberately over the back of one, and then perches itself on the top of another as if to get a better view of the surroundings. In either case a croak of dissatisfaction may be emitted by the creature so unceremoniously treated, but the sound is generally much shorter and far less musical than the love songs of a spring evening.

But there is another and very different sound produced by the frog—a rather sharp and piercing cry, much resembling that of a young child in agony, and emitted, as far as my experience goes, only when the creature is in great terror. I first heard this peculiar cry proceeding from near the bank of a brook, at the bottom of a meadow; and, on hastily approaching the spot, saw a full-grown snake with the hind leg of a struggling frog fast in its jaws; and since that time I have on several occasions heard the same sound produced by frogs similarly surprised; and if the power and frequency of these cries may be taken as a measure of the agony of the creatures concerned, it is certain that the frog is far more terrified by the painless grasp of a snake's jaws than by the clutch of a human monster.

We have already said that frogs feed freely during the warmer months, and that they do not as a rule take any food in the winter, so that our observations on their capacity for taking nourishment and their methods of capturing and disposing of their prey should be taken in the spring and summer. At these seasons we should supply them liberally with their favourite viands—worms, caterpillars and other grubs, flies, moths, beetles, &c.

Here is a fly, crawling up the glass of the vivarium. Let us watch what will happen. One of our frogs immediately prepares for action. The fore part of its body is raised by its outstretched arms; and, with elevated head, it keeps its eyes steadily fixed on the unwary insect, as yet safely out of reach. As the fly crawls round toward the corner of the case, the watchful frog now and again takes a single quick step in the direction of its prey; and, when at last the insect comes within range, with a vigorous leap it makes a dash against the glass. The frog of course falls to the bottom again, but, like a cat, almost invariably settles on its feet. And as for the fly, it disappeared so suddenly that we are doubtful whether it is captured or has escaped, until a muscular movement in the frog's forequarters tells us that the act of swallowing is in progress.

So rapid are the motions of the frog that we have some difficulty in deciding how the feat of capturing its prey is accomplished; but a close and careful observation of the act will show us that its tongue is thrust out with lightning-like rapidity as the creature takes the leap, that the fly is held securely by the viscid saliva with which this organ is coated, and that the equally rapid retraction of the tongue causes the insect to be safely lodged in the capacious mouth, which immediately closes and effectually prevents the escape of the victim.

Let us now examine this efficient prehensile organ to see in what way it is peculiarly adapted for such an important function. After some little difficulty we succeed in opening our pet's mouth, and observe that the tongue is fixed to the lower jaw in the very front of the mouth, and that its free end, which is divided into two lobes by a depression in the middle, is directed backward. Thus it is that the owner is enabled to shoot it forward some considerable distance; so far, indeed, that when the frog captures an insect, as it often does, without taking a leap at all, the latter is seen to suddenly vanish while the front portion of the frog's head does not approach it within a considerable fraction of an inch.

FIG. 305.—TONGUE OF A FROG

When a frog attacks a large worm or grub, the mode of procedure is very different. After approaching its prey to within an inch or so, its head is suddenly thrust forward, the defenceless creature is seized at any convenient point by the frog's jaws and then, without the slightest pause, a series of the most grotesque movements follows. The frog seems to struggle unnecessarily. Its forelegs, now the right and then the left, are used to push the projecting portions of the poor victim into its mouth. A number of vigorous gulps are made, the whole of the body apparently taking part in the muscular movements, and the prominent eyeballs are each time pulled within their sockets and closed, as if a momentary darkness served to intensify the sensation of the palate. But all this lasts for only a short time, and the worm or grub, still alive and practically uninjured, finds itself safely lodged in a comparatively small digestive pouch, where it is probably slowly killed by the exclusion of air and the action of digestive fluids.

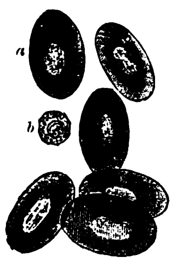


FIG. 306.—BLOOD-CELLS OF THE FROG

a, red corpuscle; *b*, colourless corpuscle

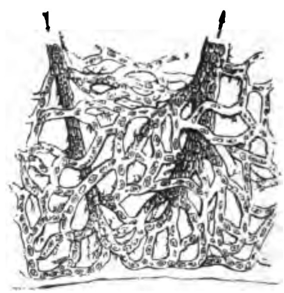


FIG. 307.—CIRCULATION OF BLOOD IN THE WEB OF A FROG'S FOOT

We have already referred to the comparatively large size of the corpuscles or blood-cells of Amphibians. These in the frog are oval in form, and one-thousandth of an inch in length, or about three times the size of the corpuscles in our own blood. This remark applies to the *red* corpuscles of the frog; but in addition to these there are others which are colourless, and these are smaller, and much fewer in number.

A microscope that will magnify up to one hundred diameters is sufficiently powerful to show these blood-cells well; and as the web between the frog's toes is very thin and transparent, there is no difficulty in observing the circulation of the blood in the living animal. The corpuscles may be seen passing with the current of colourless liquid from the smaller arteries into the capillaries, the walls of which are so very thin as to be almost invisible. The white cells, which may be seen continually changing in form, generally creep slowly along the walls of the vessels, while the red ones move more rapidly in the centre of the stream. It will be observed also that the latter are decidedly elastic; for when they reach an angle formed by the junction of two small vessels, they are often compressed by the slight pressure to which they are subjected, but resume their normal form as soon as the pressure ceases.

The Edible Frog (*Rana esculenta*)

(Plate VII, fig. 2)

It is extremely doubtful whether this is really a British species, though it is to be found in many localities in the eastern and other counties. It is well known that about fifty years ago many hundreds of these frogs, as well as large quantities of spawn, were imported into this country from France and Belgium and deposited in the Fens; and there seems to be no record of the presence of the species in the British Isles previous to this time.

Esculenta is larger than *Temporaria*, and is generally of a greenish tint, though sometimes of a rather rich reddish brown. It is conspicuously marked with darker tints, and may be readily distinguished by a pale line down the middle of the back. The dark patch which extends from the eye to the shoulder in *Temporaria* is absent in the edible species, and the latter, though very variable in colour, is generally much handsomer. The space between the eyes is usually convex in the common frog, and concave in the edible species, and the distance between the eyes is much less in the latter than in the former; the tympanum, which is comparatively small in the case of *Temporaria*, is as large as the eye in *Esculenta*. The croak of the edible frog is also louder and much more musical than that of *Temporaria*.

Fig. 308.—The Upper Side of the Head of the Male *Rana esculenta*, showing the Vocal Sacs inflated

The male *Esculenta* is provided with a pair of large pouches, communicating with the cavity of the mouth; and situated one on each side of the head, just behind the angle of the jaw. These are known as the *vocal sacs*, and are dilated to a spherical form when the animal is croaking, being then inflated with air.

These two British frogs so closely resemble each other in general structure that the brief description given of the common species applies equally well to both; and the same remark holds good concerning the metamorphoses through which they pass in their earlier days. But the edible frog is more strictly aquatic than the common species, and seems to be almost as partial to running streams as it is to ponds. It does not wander so far from the water as its relative, and is consequently not always so easily caught, being generally able to hide itself immediately by taking a plunge into a pond or stream close at hand.

This greater partiality for water is exhibited by the edible frog when in captivity. During the winter season I have generally found this creature lying in the shallow pool of water that was provided in the vivarium after all the frogs of the common species had completely hidden themselves beneath the moss and stones. And, generally speaking, it leaves the water only during very severe weather. Also, it does not seem to be so careful concerning the ordinary comforts of life as its smaller companions; for, while the latter invariably seek out or scoop out for themselves snug little beds where they can sleep in quiet seclusion, perfectly hidden from view by the substance into which they have forced their way, the edible frog, kept in the indoor vivarium, when it quits the water, generally settles down near its pool, leaving itself almost or quite uncovered.

The edible frog is to be found almost all over Europe, and, as its name implies, is valued by the epicure as well as the naturalist. At one time frog-eating was apparently the privilege of the inhabitants of France and Belgium only, but, through the influence of these enthusiastic gastronomists, the fashion has extended itself across the seas, so that stewed and fried frogs are now served in some American hotels, and preserved frogs' legs—*Fricassée de grenouilles*—are to be obtained in West-end provision stores of London.

It must not be supposed, however, that *Rana esculenta* is the only amphibian so favoured by the appreciation of omnivorous man, for several other species of frogs, and even of toads, are eagerly devoured by both civilised and barbarous races in many countries. The Chinese evidently deem frogs a luxury, and being either more economical, or else less educated in the science of gastronomy than their French cousins, partake of portions which are rejected by the latter. Both frogs and toads are eaten largely by races in South America, the West Indies, and many of the islands of the Pacific.

Although it has been the intention to deal in this volume with British life only, yet I cannot refrain from mentioning the beautiful and interesting little Green Tree Frogs (*Hyla*), so common in the south of Europe, and so often sold by dealers in London and other large towns.

These graceful little creatures thrive well in the vivarium, and live in perfect harmony with their British relatives. They feed on flies and various other insects, catching them very cleverly by a leap and a thrust of the tongue. A peculiar feature of the Green Frogs is their power of walking over a smooth perpendicular surface, holding on by the suckers which exist on the swollen extremities of their fingers and toes.

They fall in so well with civilised life that they seem to be quite friendly with their owner, and readily adapt themselves to the changed conditions. Thus, if allowed to quit their home, they may be seen walking up the window panes or the wall, catching the flies that come within their reach; and if placed on a dining-room table they freely follow the same pursuit.

During the winter time, a vivarium containing Tree Frogs should be kept indoors, and they will then rest during severe weather, either snugly packed in a top corner of the case, or hidden under moss or some other covering.

Toads

Toads resemble frogs in many points of structure, also in their metamorphoses and some of their habits; but the differences between the two are such that there is not the slightest difficulty in distinguishing one from the other.

The colour of toads is usually dull compared with that of frogs, and the skin is dry and covered with a number of little warty projections. Their bodies are broad and bulky, and the belly much swollen. The limbs are shorter than those of frogs, especially the hind pair, which are not adapted for jumping; in fact the creatures seldom attempt to jump, and when they do, the length of one leap is only three or four inches.

They are more terrestrial than frogs, repairing to the water only for a short period in the breeding season, and their toes are only partially webbed.

They breathe in the same manner as frogs, the floor of the mouth being alternately raised and depressed to pump the air, which is admitted through the valvular nostrils, into the lungs.

We have only two kinds of toads in Britain, yet we can lay claim to a rather large proportion of the European species of *Bufo*, for there are only three species in the whole continent. In fact it has been doubted whether our *Bufo calamita*, or Natterjack, is not a variety of the continental *B. viridis*; and if such is the case, then there are only two European species, and we have both.

The Common Toad (*Bufo vulgaris*)

(Plate VII, fig. 3)

The colour of this species is a dull dark brown, or sometimes a lighter ashy tint; and the general dinginess of its appearance, together with the rough and warty character of its skin, the broad and bulky form of its neckless body, and its extremely awkward gait, have all had something to do with the almost unanimous verdict that the toad is one of the ugliest creatures in creation. But if it *is* ugly, it has certainly one redeeming feature in the possession of a pair of most lovely eyes. Let those who aver that they cannot bear to look at a toad endeavour to overcome their innate prejudice for creeping things, and take one home with a determination to see if there really be any charm in it, and it is then highly probable that its bright eyes, and its curious ways, rendered more pleasing by the readiness with which the creature adapts itself to a domesticated existence, will soon enable them to look without a shudder, and even to handle the creature without experiencing the cold shiver that formerly sped throughout the body on touching its rough and chilly skin.

There are still many who consider it their duty to declare that the toad is a poisonous and destructive 'reptile,' that it can spit forth a highly venomous fluid, that it can even vomit fire from its cold and humid body, and that there is death in a mere glance from its beautiful eyes! But all these and numerous other absurd beliefs are received and handed down by persons who are naturally careless about the truth, and have as a consequence no desire to observe and investigate for themselves.

There is, however, some shadow of a reason for the frequent opinion that the toad is venomous, even though it has no sting and no poisonous bite, for its rough skin secretes a powerful acrid fluid which, from the irritation it produces, is a valuable defence against many of its enemies. I have seen a cat take a frog in its mouth, and even devour it; but one short experience of the flavour of a toad is quite enough for pussy, who sneaks away with movements and gestures that tell of an outraged tongue.

Some naturalists have made a study of this powerful secretion, and have declared that a small quantity injected into the blood of a small mammal will cause death in a very short time; but it must not be inferred from this that any danger is likely to accrue to ourselves as the result of handling toads. In this respect they are perfectly harmless, for the secretion, be it ever so irritable, will not find its way through our impermeable skins. In fact it seems to have no power as a poison unless introduced direct into the blood system, and many animals, including our own common snake, devour toads with a relish. There is no doubt, too, that toads are eaten by human beings, but I cannot say to what extent the amphibians are deprived of their venom-producing skin before they are devoured.

It is perhaps doubtful whether we are to look upon the irritating substance merely as an *excretion* thrown off by the skin of the toad in the process of blood-purification, just as poisonous matter is expelled from our own systems through the agency of the skin, kidneys, and other organs; or whether it is secreted as a means of defence: but the latter theory is more probable, for observers declare that the amount of the irritant exuded by the skin is much greater when the toad is disturbed and apparently in danger—that the defensive fluid is secreted fastest just when it is required for defensive purposes.

Bufo vulgaris starts from its winter quarters early in the spring, and repairs to the water in April. Here the eggs are deposited in long chains, generally a few weeks later than those of the frog, and as soon as this duty is over it quits the pond for the remainder of the season.

The tadpoles are very similar to those of frogs, but are darker in colour, and are often so numerous as to give the appearance of a black mud entirely covering the bed of the pond in which they exist.

Let us now observe some of the movements and funny ways of our captive toads. We remove one of them from its corner where it is wont to settle down in quiet during the hours of daylight. If it is an *old* friend it takes its new position almost as a matter of course, as if it thoroughly understood that it is expected to remain still during the coming inspection; and when the examination is over, crawls away to the same quiet nook with a laboured and awkward step. Being now no longer in fear of its familiar master it never attempts to leap, though when first captured it did occasionally jerk its clumsy body forward to the extent of the length of its hind legs.

But if the toad selected for observation is a recent captive it will at once make sundry protests against the unprovoked assault. As soon as it is touched it puffs out its already bulky body by inflating it with air in such a way as to remind us of the 'frog in the fable,' who lost its life in endeavouring to reach the dimensions of an ox; and if its master persists in the unlooked-for intrusion the toad still further attempts to fill its tormentor with fear by lifting its body on its straightened legs till its stature is more than doubled, and till it looks something like a headed balloon supported on four short posts. This same comical attitude is also almost invariably assumed when a toad is approached by a snake; and should the latter attempt to swallow the toad, the difficulty of its task is greatly increased (especially if the toad be a large one) by the volume of air which the body contains, and which is not to be expelled by the pressure of the snake's jaws. I have seen the inflation of a toad's body carried to such an extent that, when held up to the light, it was a veritable air-ball, so transparent that the backbone with its surrounding muscles could be easily traced, and the internal organs could be seen occupying only a very small proportion of the cavity, mostly near the head.

The feeding of toads is as interesting to the observer as that of frogs. The creatures are all at rest, drowsy and lethargic. We drop a worm an inch or two from one of them. Immediately the toad is full of life. Its eyes brighten, its head is turned sharply toward the anticipated meal. Every movement of the worm seems to add to the vivacity of the toad. The latter takes a sharp step towards its prey; it breathes quickly and twitches its toes with excitement; and then, with a sudden thrust of the tongue, it seizes the poor worm, which, after a few gulps, assisted by a few awkward movements of the toad's forelegs, rapidly disappears from view.

Flies, beetles, grubs, and other small creatures are captured by the tongue after the manner of the frogs, this organ being similarly adapted for the purpose, but differing from the tongue of the frog in that it is only very slightly notched at the tip.

Both frogs and toads frequently make the mistake of attacking a worm that is too large to be accommodated with ease in the offender's stomach. After very great efforts on the part of the batrachian the poor victim nearly, or perhaps entirely, disappears. But the aggressor is ill at ease; and, having found out its mistake, it suddenly and forcibly ejects its exhausted prey with a gesture that suggests pain and disappointment. However, the affair does not always end here. The batrachian often has another try, which is sometimes more satisfactory, but it may end in the same inglorious way as the first attempt.

The toad, like its relatives of its own and the *Rana* genera, very seldom attacks a creature that is not moving. Often, when it is just ready for the fatal thrust, the anticipated prey ceases to move. It then watches closely for a short period, and if no further signs of life are exhibited it will leave in search of more animated scenes. But the toad is easily deceived in the matter of motion. Just as a child in a moving train fancies that the outside landscape has taken to flight, so to a toad that is moved all motionless objects seem to be active. Hold a dead worm before a tame toad, and it refuses to snap at the dainty. But suspend the worm by a thread, and, taking your pet on your hand, move it up and down or from side to side near the morsel. Things now look different to the toad, and probably the meal is as much enjoyed as if the worm were actually alive.

I may mention one other fact concerning the toad, which also, by the way, characterises its fellow-batrachians, viz. the periodic casting of the skin. If you keep toads in confinement you will occasionally observe one making its appearance in a somewhat altered garb. Its coat is lighter in colour, and the markings are more distinct. You come to the conclusion that it must have cast its old coat, and you make a search for the old garment, but in vain. But this is an event of rather frequent occurrence—probably four or five times at least for each toad during one season—so that probably before long an opportunity will present itself for the solution of the mystery.

When a toad is about to cast its skin it nearly always retires to a quiet nook. At first the skin splits down the back and along the top of the head. The latter is soon released, and the creature, seemingly very uncomfortable with its ragged coat hanging over the sensitive skin, continues to struggle to get free from its useless encumbrance. Both fore and hind limbs are used to rub off the loosened coat; and, often before the whole is free, the toad commences the economical operation of swallowing the whole of its cast-off wardrobe.

Apparently the toad can dispose of its skin at will, or else the process is accelerated by a change of condition, for the removal of the creature from one kind of home to another—from the garden to an indoor vivarium, for example—will almost invariably lead to a change of garment.

THE NATTERJACK TOAD (*Bufo calamita*)

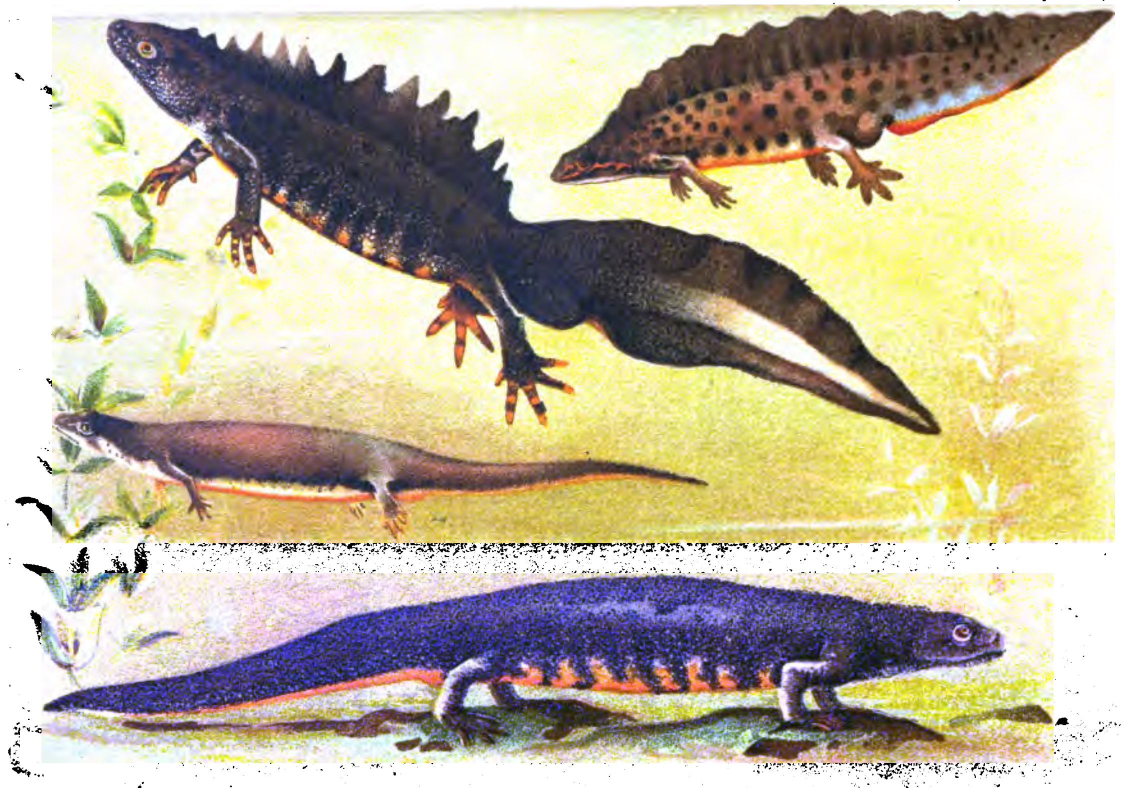
Although the Natterjack is very similar in general build and appearance to the common toad, it is easily distinguished by its yellowish or olive-brown colour and the pale yellowish line that runs down the middle of the back. The warts on its surface are also more prominent, and exhibit a decidedly reddish tinge; but the dark marblings of the skin, which are generally rather conspicuous in the common species, are less distinct in *Calamita*.

It is further characterised by its nimbleness, being far more active and less awkward in its movements than its vulgar cousin. Yet it never attempts to jump, not even when pursued, but crawls away quickly or even *runs*. Natterjacks are rather gregarious in their habits, one being seldom seen alone. I once met with quite a colony of them in a patch of wooded upland in Hampshire. The first one that attracted my attention ran quite briskly under some dead leaves that filled a deep rut in the roadway. In the twilight I mistook the creature for a small mammal, but a search among the leaves soon revealed two natterjacks—a 'find' that was immediately followed by the capture of several others.

At one time this species was moderately common in several localities round London, but it now seems to have almost quitted the neighbourhood of the metropolis. In the fens and various other marshy districts it is still common; and during the summer it wanders far from the water, often journeying over high and dry moors, where it is protected from the blazing sun only by small furze clumps, heather, and scanty grasses.

The activity of the natterjack as compared with the common toad is shown not alone by its running, for it is equally expert as a digger. When about to rest it scoops out a comfortable hollow in the ground, where it lies in perfect safety, and sometimes burrows

PLATE VIII.



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to the depth of several inches. It is also a good climber, but, like the common toad, succeeds best in this manœuvre when working its way up a crevice through which it can force its body by means of its knees. In this way both *Vulgaris* and *Calamita* will sometimes ascend old walls and hollow trees.

The eggs of *Calamita* are laid in strings of great length, and are generally deposited in May or the beginning of June; and the metamorphoses are not completed till the end of the summer or the autumn.

Newts or Efts

The three species of British newts or efts have so many characteristics in common that it will be well to deal with their general features before mentioning their individual peculiarities, and thus avoid an unnecessary repetition.

Compared with the preceding Batrachians their bodies are long and slender, and their legs short and equal; and the tail, which in frogs and toads disappears in the process of development, remains permanent in the newts.

The general form of a newt is very similar to that of a lizard, and this resemblance has led to the common application of the name 'water lizards' to the former. But, to avoid confusion, it may be well to note the more obvious distinctions between newts and lizards. Newts are amphibious animals, and even truly aquatic at certain periods of their existence; while lizards inhabit dry heaths, moors, and banks. Newts have a soft moist skin, resembling that of frogs; but lizards are covered with a dry scaly skin, much like that of a snake. Newts have flattened tails adapted for swimming, while the tails of lizards are round and tapering. Also, newts in their earlier days, pass through a series of stages similar to those of the frog; but young lizards, on their first appearance in life, are formed just like their parents. And, further, the close relationship existing between the newts and our other amphibians is clearly exhibited by the shape of the head and the wide gape; by their prominent eyeballs, which are retractile, and readily observed on the roof of the mouth, and by the arrangement of the eyelids; also by their method of breathing, which corresponds exactly with that force-pump action described when treating of frogs.

During a large part of their existence newts are very inactive, for they hide under the cover of walls, stones, &c. during the summer days, and creep about leisurely in search of food at night; and throughout the periods of severe weather they remain motionless in their retreats. This will account for the generic name—'*Molge*'—a name derived from the Greek and meaning 'slow.'

Newts are most active during early summer—from April to the end of June—at which season they are to be seen in almost every pond, and this is the best time to procure them for study and for the ornamentation of our aquaria.

They are easily caught. The only implements required are a small gauze hand-net and a large metal box, such as an ordinary bait-can, in which to convey the specimens home.

As you walk round a weedy pond you will observe here and there a newt gracefully swimming with an undulatory movement of its tail toward the centre. Its fear of the monster on the bank is evidently not very great, for its flight is not at all hurried, neither does it trouble to swim any great distance from you; and a quick sweep of the net among the weeds will generally secure the prize, and often one or two others that happened to be among the foliage in the path of the net. Sometimes, in fact often, the newts in a pond are so numerous that they may be secured, five or six at a stroke, without attempting to look for them, but by simply sweeping the net haphazard among the weeds.

The schoolboy's method of catching newts is usually not so productive, though it may be more exciting. An extempore fishing-rod is made of a cut stick and a piece of string. An earthworm is tied to the lower end of the string and let down into the water, either just in front of a newt that is seen or in a spot where some of the creatures are supposed to be hidden. A gentle tugging is presently felt, and is sometimes rendered visible by the bobbing of a piece of cork used as a temporary float. Now is the time for the exercise of a little patience, and judgment. Give the hungry amphibian sufficient time to swallow the worm, or, if the latter be a large one, time to get a portion well lodged in its stomach; and then a sharp haul lands the creature on the bank before it has had time to free itself from the treacherous luxury.

During early summer the female newts are busily engaged in the deposition of their eggs. These are not laid in masses like those of frogs, nor in the long strings after the manner of toads, but deposited singly on the leaves of aquatic plants. It is interesting to watch this procedure in the aquarium. While the egg is being deposited, the hind legs of the newt are brought against the opposite edges of the leaf that is to support it, and in this way the leaf is curled in such a manner as to partially enclose the egg. The value of this precaution is evident to those who have seen the lively little stickleback and other small fishes snapping away at the ova almost immediately after they have been laid; but I am very doubtful whether this instinctive action on the part of the female newt is as protective as is generally supposed. Very frequently the leaf which is curled as the egg is being deposited is sufficiently elastic to regain its original form as soon as the pressure is removed, and those leaves which remain curled generally leave the egg more or less exposed. Moreover, I have often observed the newt lay its eggs on the flat surface of a large leaf which it made no attempt to curl, or which was so large and rigid that any endeavour on the part of the creature to conceal the egg would be useless, and this when the aquarium contained other aquatic plants which might have served its purpose admirably.

Again, how does the newt manage when in a pond which contains no aquatic plants at all?—and we often find them in such. This may be answered by doing a little dredging in the pond during the breeding season, when the eggs will be found attached by their gelatinous covering to pieces of stick, dead leaves, and various other substances, and generally laid without any apparent attempt to conceal them.

The segmentation of the ovum is very similar to that of frogs and toads; in fact the whole early history of newts is much like that which we have somewhat fully detailed in the case of the common frog; but there are a few interesting peculiarities which may be noted. The external gills of the tadpole of the newt are longer and more plumelike; its suckers also are longer. Its forelimbs appear first, and not the hind pair as in frogs; and, as has been already noticed, the long tail is permanent.

The tadpoles are easily caught with a net, but if it is desired to keep them alive they must have plenty of room and be well supplied with weeds; otherwise they will almost surely become addicted to cannibalism till only a few survivors remain.

Then, again, it must be remembered that young newts leave the water soon after they have assumed the adult form, and that they do not generally return to it again till they reach maturity three or four years after. So if you are desirous of rearing them throughout their early years, they must be allowed to leave the aquarium as soon as they begin to make attempts to climb out of the water, and must then be placed in a little outdoor nursery in a shady and damp corner where they have the shelter of a rockery, and where they are likely to find abundance of worms and insects for food. On reaching the period of adult life they wander about in the spring time in search of water in which to prepare for their progeny.

Nothing will suit them so well at this period as a small pond well supplied with aquatic plants; but as it is impossible to watch their movements with ease in such a home, a few may be transferred to a glass-fronted aquarium for observation.

FIG. 309.—YOUNG NEWT (*Molge vulgaris*), JUST BEFORE THE FINAL DISAPPEARANCE OF THE EXTERNAL GILLS

The adult newts generally remain in water throughout the spring and early summer, and if kept in captivity during this season they must be fed occasionally with worms—the common earthworms of the garden; this will furnish an opportunity of witnessing another phase of newt nature.

We throw a small worm into the aquarium. Presently a newt is attracted by its movements, and swims gently toward it till within a quarter of an inch or so, and then snaps at it suddenly. In another minute or two the struggling worm has entirely disappeared.

But if the worm happens to be a larger one, say about three or four inches long, the matter is not quite so simple, and may end in disappointment to the newt as well as death to the poor worm. Newts do not know the most effectual way of seizing a worm, and frequently make the mistake of snapping at the middle and commencing to swallow it at that point. In this case the newt has to labour against the double thickness which has to pass through its mouth and gullet. This often proves too much; and after many severe struggles to dispose of its prey, it is obliged to relieve itself by disgorging it entirely.

If, however, it is more fortunate in seizing the worm at one end, there is generally a trouble of another kind awaiting it, for one of its fellows, attracted by the furious struggles of the poor worm, makes a dash at the other end! Then follows an exciting scene. Both newts continue to swallow the worm, till at last their jaws meet, each one having disposed of about one half. But still they go on, each one taking gulp after gulp, with a vantage sometimes on one side and sometimes on the other. After a time, however, the weaker newt shows signs of exhaustion, and, relaxing its hold on the worm, allows each gulp of its fellow to deprive it of a portion of the meal that had already been swallowed; and then, finding no hope for the retention of the meal, suddenly ejects the remainder and swims away. But the fortune of the sole possessor of the worm is no brighter, for its stomach is distended to its greatest capacity at the time that the whole was left to its share; and after many unsuccessful attempts to dispose of the free end, it is obliged to eject even that which had been so satisfactorily disposed of.

There is yet another feature of interest common in our newts, viz. the periodical moultings or castings of the outer skin. You may sometimes observe in your aquarium a newt with a little loose skin, very thin and transparent, hanging from its head or neck. Watch this one carefully, and you will notice peculiar movements of its body and limbs not observable in the others. Its fore-limbs are occasionally brushed over the front part of its body as if to remove the cause of some troublesome irritation. It also swims between the weeds, rubbing its body along the stems and leaves, and sometimes turning itself on one side to better perform its task. All this time the skin is seen to be gradually peeling off, till it hangs beside the tail as the creature moves through the water. The movements above described are continued, assisted now by a rubbing of the hind limbs; and before long the delicate skin, with two pairs of exceedingly fragile but perfect gloves, may be seen floating freely in the water. Often this old coat is immediately devoured by the creature that cast it. Sometimes another will make a meal of it. But frequently it remains floating for a long time among the weeds, or settles at the bottom.

Take the skin out of the water and it immediately becomes a shapeless and almost invisible film, hardly to be moved without injury. Although so delicate it can be easily preserved as a permanent specimen for a museum of animal curios and treasures. For this purpose it should be placed in a small bottle or specimen tube with sufficient water to enable it to float freely. Then a few drops of spirit—not more than one-fourth the volume of the water—should be added.

Having now dealt with a few of those characteristics which are common to the three British newts, we will proceed to note those peculiarities by which we are enabled to distinguish between them.

The Great Warty Newt (*Molge cristata*)

(Plate VIII, figs. 1 and 2)

This is the largest of our newts, and measures from five to six inches in length when fully grown. It may be known at once by the rough warty skin which gives it its popular name. Its colour is very dark—almost black—above, but the under side is a beautiful bright orange colour, relieved by bold and irregular black markings. Along the sides are numerous white spots, and a loose fold of the skin forms a kind of collar round the neck.

There is not much difference between the sexes till they reach maturity—that is, when they repair to the water for breeding purposes in the spring of their fourth year. At this period the skin becomes much rougher, the little warts, hardly visible before, now becoming very prominent. The colours also grow brighter, and a conspicuous, deeply notched crest gradually develops on the back and tail of the male, and the light-coloured stripe on each side of the tail becomes a beautiful silvery blue.

The deposition of the eggs begins in April, and continues to the end of June or even into July; and the autumn is well advanced before the latest tadpoles have undergone their metamorphoses.

Each egg consists of a thin and transparent membranous capsule, containing a white yolk suspended in a colourless fluid, and surrounded by a gelatinous envelope which glues it in its place.

In three or four weeks the young tadpole is free, and in about another month it is provided with its fore pair of limbs; but it is usually quite five months after the hatching of the egg before the hind limbs, the lungs, and the other permanent organs of the adult form have so far developed that the young newt is in a position to ramble at large on *terra firma.*

The growth of the newt is now slow compared with that of its earlier career, the increase in its length being at the rate of about an inch each year; and when fully grown, at the end of its fourth summer, it measures from five to six inches.

It has often been asserted that newts never return to the water from the time of infancy till the age of maturity, but *Cristata* is certainly an exception to this rule. I cannot say that every one of the species returns to the ponds each summer; in fact it would appear to be otherwise, for nearly all that are taken with the net are either very young ones just undergoing their transformations, or are those of mature years; but I have taken specimens of all ages—one, two, three, four, or more years—from the same pond at the same time.

Towards the end of the breeding season the crest of the male begins to grow smaller, and his colours to fade; and as the autumn sets in, both males and females wander out of the pond, often to some considerable distance, and seek out a snug hole in which to spend the winter, several often huddling together in the same little nook.

Cristata is a common species, and widely distributed. It is particularly abundant in the ponds round London, even in close

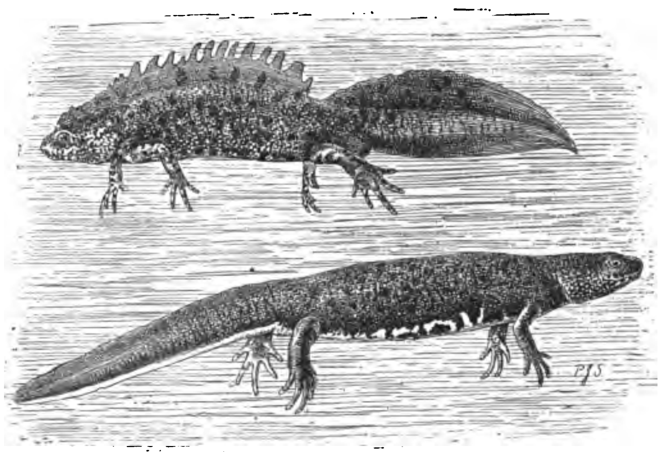

FIG. 310.—MALE AND FEMALE *Cristata*, REDUCED IN SIZE

proximity to suburban dwellings and in the ponds and ditches of the outlying commons. But, in the former case by the untiring industry of the builder, and in the latter by the efforts of the authorities to remove all traces of wild Nature from our recreation grounds, our cockney batrachians are being rapidly annihilated or else driven away from the outskirts of town.

THE COMMON OR SMOOTH NEWT (*Molge vulgaris*)

(Plate VIII, figs. 3 and 4)

This is by far the commonest of our newts, for it is to be found in ponds and ditches almost everywhere; and, at times when it prefers to live on land, may be seen snugly housed in the daytime under loose bricks and stones quite within the precincts of our towns, or under the shelter of garden walls, and even in damp cellars and outhouses.

It is about four inches long when full grown, and its skin is smooth and very variable in colour. The back and sides are either yellowish, grey, brownish or olive, and spotted with a darker colour. The spots are larger and more numerous in the male than in the female, and the general appearance is always much brighter during the breeding season than at any other time. On the head are five dark streaks, more conspicuous in the male sex. One of these runs longitudinally along the middle of the head, but does not extend quite to the front. Two others, one on each side of this, almost meet in front, forming a large V; and the remaining two lines are broken by the eyes.

The under side is yellowish generally, but of a bright orange in the spring, and is boldly spotted with very dark brown or black.

In the breeding season the male is provided with a notched crest along the back, extending to the tip of the tail; and the tail is also deeply fringed below. The female, too, is crested, but the crest is very narrow and is not notched.

As with *Cristata*, the crest gradually disappears as the summer advances and the breeding season terminates; but it would seem that this season may be prolonged into very late autumn if delayed by a very severe spring, or commence very early in the year when the spring is exceptionally mild, for I have repeatedly taken both the undeveloped young newts and also the adults with full crests in the months of December and January when the weather has been mild.

It will be noticed that the feet of *Vulgaris* are not fully webbed and adapted for swimming, but that the toes are only slightly fringed. Even this is hardly observable in the female, and in the male the fringe disappears with the crest towards the autumn. The tail is the chief organ of locomotion, and the legs are used to assist the progress of the creature only when it is moving on land, on the bottom of a pond, or among very dense weeds. When it is swimming, therefore, the legs are a barrier to its progress by offering resistance to the water. But this resistance is reduced to a minimum by the creature's habit of bending them backward while it is swimming. At this time the movements of *Vulgaris*, and especially of the male, are rendered exceedingly graceful by the undulatory movements of the broad and prettily coloured tail and the easy position of the apparently loosely jointed limbs.

According to some observers the eggs of the common newt are

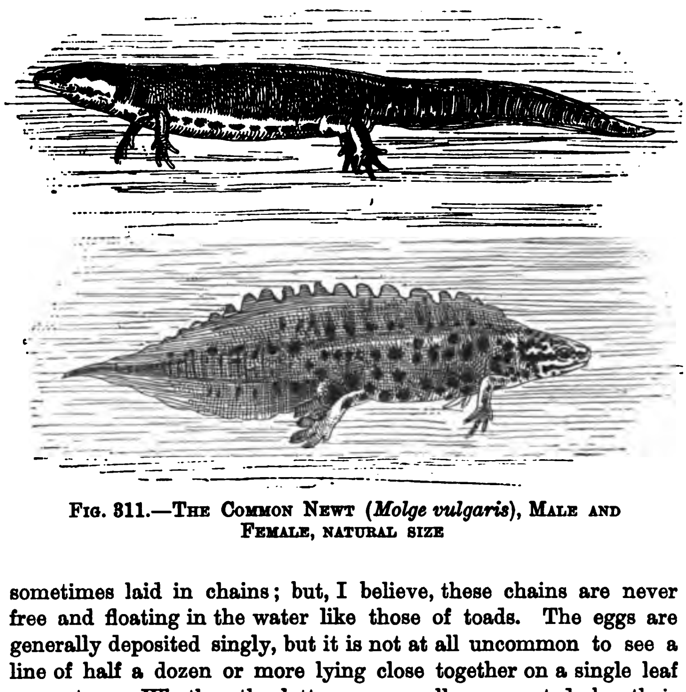

FIG. 311.—THE COMMON NEWT (*Molge vulgaris*), MALE AND FEMALE, NATURAL SIZE

sometimes laid in chains; but, I believe, these chains are never free and floating in the water like those of toads. The eggs are generally deposited singly, but it is not at all uncommon to see a line of half a dozen or more lying close together on a single leaf or a stem. Whether the latter were really connected by their gelatinous envelopes at the time of laying, or whether they simply lie in contact, I cannot say; but where such rows of eggs exist a number of isolated ova are almost invariably found; and if we watch the female *Vulgaris* while engaged in the act of laying, we shall observe that the eggs are often deposited singly at considerable intervals of time, and that she often travels from leaf to leaf and from plant to plant during these intervals.

If kept in captivity *Vulgaris* exhibits a marked aversion to the water towards the end of the summer, and manages to get out of an ordinary glass aquarium with ease if there is no cover to prevent its escape. Of course the glass is much too smooth to admit of ordinary climbing, but the newt's toes, especially after having been above water for a short time, become partially dry and stick to the glass, and so allow it to pull itself a little way up. Then the skin of the belly, and, a little later, that of the hind toes, also assist in supporting the body, so that the creature can steadily creep up the glass.

It is perhaps hardly necessary to add that, in spite of all the ill things that have been said of newts, all the three species are perfectly harmless. It has been said that they sting, that their bite is poisonous, that contact with their skin is dangerous, that horses which drink out of a pond in which they exist will certainly die. But there is not the slightest foundation for these and the various other superstitious beliefs that have been and are still held by the thousands who are willing to condemn the creature without a trial.

The Palmate Newt (*Molge palmata*)

This species is not nearly so abundant as the two preceding, and is decidedly local. It was first recognised on the Continent a little more than a hundred years ago, and first recorded in Britain about fifty years since.

Specimens have been taken in Devon, Herefordshire, Somerset, and various other counties of England; also in Scotland, more particularly in the south.

Palmata is considerably smaller than *Vulgaris*, and may be further distinguished by the following characters:

The colour is an olive-brown above, marked with darker spots which are much smaller than those of *Vulgaris*; and underneath it is a bright yellow or orange. The female is much paler than the male, but the darker markings are similarly arranged. During the breeding season the male is crested, but the crest is very dark, and much narrower than that of the last species; its edge is also quite free from notches. The female, too, is slightly crested, and has a yellow fringe on the lower edge of the tail.

The tail of the male is very blunt at the extremity, looking almost as if it had been cut, but it terminates in a slender filament. That of the female is more pointed, and the filament is almost entirely absent, being represented by only the tiniest projection.

Another peculiarity of the species is a projecting fold of the skin forming a longitudinal ridge or keel on each side of the body, and giving it, together with the crest on the back, a somewhat triangular appearance.

Further, the feet of the male are generally of a very dark colour, and the toes are fully webbed during breeding time; but, as with *Vulgaris*, the web gradually disappears with the crest, late in the summer, the toes becoming free and cylindrical in form.

It will be observed from the above remarks that the chief of the distinguishing characteristics of the present species belong to the male only; and on this account there may be some difficulty in the identification of the females, which closely resemble the same sex of the last species in general appearance. But this difficulty vanishes when the two are examined side by side.

INDEX

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